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A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

We have learned with deep regret of the death of Dr. Frederick Muir in England on May 13, 1931. His work in the biological control of insect pests of sugar cane in Hawaii is a notable record of achievement in science and an outstanding influence in directing the economic entomology of the world toward the control of injurious insects by biologic means.

His work with the Experiment Station of the Hawaiian Sugar Planters' Association began in 1905. This was shortly after Dr. R. C. L. Perkins and Albert Koebele had made successful introductions of the egg-parasites of the sugar cane leafhopper.

Soon after that he undertook to find a natural enemy of the cane borer (*Rhabdocnemis obscura*) and after years of discouragement and illness contracted in his explorations, he discovered and successfully introduced to Hawaii the tachinid fly (*Ceromasia sphenophori*), largely reducing the heavy damage to cane crops caused by the borer since the beginning of the sugar industry in Hawaii.

In 1913 a new pest, an Anomala beetle (*Anomala orientalis*), had put in its appearance on an Oahu plantation and Dr. Muir, having traced its habitat to the Orient, proceeded to Japan in the search of its natural enemies. So much unsuccessful work had been done against similar root grubs in Porto Rico and Illinois, that little encouragement was found for the success of this venture.

The parasites which he found in Japan failed to become established in Hawaii, but his firm conviction in the biologic method of fighting insect pests did not waver. After continuing his work in Formosa he went to the Philippines, where the species of Anomala he was working to control did not in fact occur. But here he found a Scolia wasp (*Scolia manilae*) that was parasitic upon an allied species, and this on introduction to Hawaii became an effective enemy of *Anomala orientalis* and checked it to such an extent that it has not spread beyond a limited area.

Later, after observing the troublesome outbreaks of the sugar cane leafhopper that occurred despite the presence of the egg-parasites introduced fifteen years earlier, he held that since similar outbreaks did not occur in Australia and Fiji, other natural enemies of the leafhopper could be found. It was after a year of effort in Australia that his prediction proved to be correct. He found and intro-

duced to Hawaii an insect (*Cyrtorhinus mundulus*) that feeds upon the eggs of the leafhopper and this perfected the control of the pest that had taken such heavy toll from the sugar crops of the Hawaiian Islands.

While these professional achievements of Dr. Muir were along economic lines, his interest in the fundamental science of entomology was great. He believed that there was no dividing line between pure and applied science, that the two were inseparable. He was the author of many contributions to journals of entomology.

Dr. Muir was born in London, April 24, 1873. A large part of his earlier years were spent in Africa. In his death Hawaii loses a prominent benefactor, and one whose work stands as an inspiring example.

In This Issue:

Biological Control of the Coconut Moth in Fiji:

Dr. Muir's review of the book on the Coconut Moth in Fiji that was published last year appears with comments on various phases of the work involved in securing a parasite which was introduced and now controls the pest. Parallels are given between this work and some of our parasite introduction work in Hawaii.

Root Studies in Coimbatore:

In view of the increasing interest taken in the sugar cane root studies in these Islands, an account is given in this paper of the researches of the Coimbatore Station on this important subject.

Diseases, Malformations and Blemishes of Sugar Cane in Hawaii:

An outline presenting as near as possible a complete list of known diseases, malformations and blemishes affecting sugar cane in Hawaii is given. Following each disease the name of the causal agent appears.

Value of the Upper Joints of Cane:

An article supplementing a previous article of the same title based on experimental work of the writer, showing the approximate amounts of recoverable sugar in the upper joints of the cane stalk. An external reference point is given for locating joints of various qualities. Cost data are included for the items entering into the total cost of obtaining varying amounts of recoverable sugar.

Weather and the Quality of Juice at Ewa:

This paper deals with the specific relation of weather factors—such as sunshine, temperature, etc., to the average quality of juice of a typical irrigated plantation.

The significant fact is brought out that weather conditions exercise a very great influence on the average quality of juice of even an efficiently irrigated plantation. At Ewa, bright sunny days and cool nights are found to be the most important factors in improving the average quality of juice.

The Problem of Juice Quality:

With intensive fertilization and improved cultural practices, the yield of cane per acre has risen steadily during the last twenty years. The average quality of juice, on the other hand, has gone down just as steadily, so that today the average quality is only 60 per cent of what it used to be twenty years ago.

Added to this problem of gradual decline in the quality of juice, is the other problem of the great fluctuations in the juices from year to year.

Do these fluctuations and also the steady decline arise from any of our cultural practices or are they the work of some outside agencies—say weather conditions? For a proper understanding of this problem, we need to know all about the factors affecting juice quality.

In this paper is assembled information from various sources on the subject.

Cane Breeding in Coimbatore:

The good work of the Coimbatore cane breeding station is being increasingly recognized outside of India; we have recently imported several of its promising seedlings.

This paper gives a brief account of its researches and of what it has done for India from its start in 1913 to this day.

China as a Potential Sugar Market:

An interesting article in that it gives one an idea as to what conditions will have to be met before the per capita consumption of sugar by the Chinese is increased.

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The Biological Control of the Coconut Moth (*Levuana iridescens* Beth.-Baker) in Fiji

By F. Muir

The publication of *The Coconut Moth in Fiji,* by Messrs. J. D. Tothill, T. H. C. Taylor and R. W. Paine, is a notable event in the history of biological control of insect pests. It is of interest to entomologists in Hawaii for the reason that they have had personal contact with the entomologists of Fiji for a number of years, and there has been a number of return visits between them. Thus they have come to know one another's problems fairly well.

In 1905, when I first visited Fiji, this moth was confined to a part of the island of Viti Levu, although it had then been known in the island for nearly thirty years. It was then causing the authorities anxiety, and I was consulted by the Governor, and the Superintendent of Agriculture, as to possible remedies. I advised biological control measures, and suggested some of the islands in the Southwest Pacific as the probable home of the moth, and therefore the most likely place to find suitable parasites. I believe Albert Koebele had given similar advice some months earlier. The Governor, who was also a well-known zoologist, appeared interested in the idea, but it was twenty years before the advice was acted upon. It would be interesting to know the various reasons for the long delay. One reason, I feel quite sure, was the attitude of antagonism of most economic entomologists to biological control in 1905, and for some ten or fifteen years after. Except for a small group of entomologists in the United States, a small group in Hawaii and a few individuals in Europe, the whole of the economic entomological world was opposed to this principle of control. In 1910, a leading British economic entomologist told me that I was a fool for wasting my time; that I should do no good but a lot of harm. Time brought a change, and this entomologist lived to advocate biological control himself, although he never had a proper understanding of the subject. One of the factors bringing about this change was the economic success attained in the Hawaiian Islands.

It is possible that this coconut pest could have been controlled by artificial means, but the expense would have been greater than the industry could bear.

One of the things that has been brought out in the report is the gregariousness of *Levuana iridescens,* but I do not think enough use has been made of this to account for its slow rate of spread, and for some of its most marked characteristics. The larvae, upon hatching from the eggs, do not disperse, but feed together, and only the exhaustion of the food compels them to move to another leaf, even when full grown they do not seek solitude to pupate, like so many moth larvae, but congregate together to such an extent as to lead to the death of many pupae.

The adult has well-developed wings and, if endowed with a wanderlust, would soon have spread over Viti Levu, and even to other islands; but it has a strong nostalgia and will not seek new quarters, even to oviposit, but prefers leaves upon

which Levuana larvae are feeding. This leads to the enormous Levuana population in small areas, to the destruction of all its food plant and to the great economic loss; it also is accountable for the very slow spread of the insect. This psychology also played an important part in the control by the introduced Tachnid (*Ptychomyia remota*), as the percentage of parasitism as a rule can rise higher in dense than in sparse populations.

We have a somewhat parallel case in Hawaii in *Anomala orientalis.* This beetle spread very slowly, and increased to enormous numbers in the area of infestation. When the Anomala population became very dense it was often decimated by bacteria. The adult is a good flyer and it was a problem to account for its slow spread, as they were taken feeding on several plants. It was soon found that only males, and females that had already oviposited, frequented flowers; it was seldom that a gravid female was taken feeding. Mating takes place as soon as the female matures and she deposits her eggs in the vicinity. This was an important factor in its control by *Scolia manilae* as the parasite did not have to expend much energy in seeking its host. Thus we see a parallelism due to different causes.

Ptychomyia remota is not a native parasite on *Levuana iridescens,* but is attached to other, but allied, genera in Java and Malay States; *Scolia manilae* is also attached to allied species of Anomala in the Philippines, where *A. orientalis* is unknown. These two parasites have perfect control over their hosts in their new habitats. This indicates that it may be possible to use a foreign parasite to control a native insect under certain conditions.

It is fortunate, from a scientific viewpoint, that no other death factor of importance was established along with *Ptychomyia remota,* as it demonstrates once more what a single parasite can achieve under favorable conditions. Tachinids have a wonderful faculty of finding their hosts, and therefore their critical point of parasitism is often high. The Tachinid on our own sugar cane beetle borer finds its hosts, although they are embedded in the stalk of the sugar cane. The fecundity of *Ptychomyia remota* is very much lower than that of *Ceromasia sphenophori,* but then the former places its eggs upon its host, whereas the latter has to deposit them in the runs of the beetle borer larvae, and the Tachinid grubs have to find their host for themselves. The more direct the contact between the host and parasite the less need for high fecundity.

As *P. remota* has alternate hosts in Fiji it is likely to spread beyond the range of Levuana, and so be on the spot should Levuana spread. This is the case with *Scolia manilae,* which exists on Adoretus far beyond the present range of Anomala.

The account of Chalcid B and Chalcid A on Artona in Java (p. 240), and the injurious effects the latter has upon the former, recalls the limiting effect the hyperparasite has upon the Dryinidae in Hawaii.

In studying the Levuana work in Fiji, entomologists in Hawaii will find a number of phases of interest, on account of their similarities to those of their own work.

As the three authors spent some time in Hawaii, it is strange that the only reference to the work there is incorrect. They state that the beetle borer

(*Rhabdocnemis obscura*) threatened to destroy the sugar industry in Hawaii, and that its parasite (*Ceromasia sphenophori*) was introduced from Java. This Tachinid parasite is not known in Java, but in Amboina, Ceram and New Guinea, and was introduced from the last mentioned locality. The beetle borer has been in Hawaii for over sixty years and the sugar industry expanded in spite of it. It is true that it exacted a heavy toll during all these years, but it never threatened the life of the industry. It was the leafhopper (*Perkinsiella saccharicida*) that did this, and *Anomala orientalis* might have ruined some of the most fertile areas of the Islands if it had not been controlled.

The Coconut Moth in Fiji is published in a beautiful manner, the letter press and illustrations being exceedingly good. The Imperial Institute of Entomology must be given the credit for this.

The entomologists in Hawaii, through considerable experience, are well acquainted with the difficulties and dangers of all such work, and they congratulate all those who took part in finding and introducing and establishing *Ptychomyia remota* in Fiji.

Value of the Upper Joints of Cane

By W. L. McCleery

In a previous article (1) the writer pointed out the importance of adopting some systematic method for the proper topping of cane. Purities of the juices in the individual upper joints, starting from a reference point, were given together with values in terms of recoverable sugar. The data given in the preliminary report were from one series of determinations only. Shortly afterwards, ten other sets of experiments were run and the data herein presented are based on the entire eleven series of determinations.

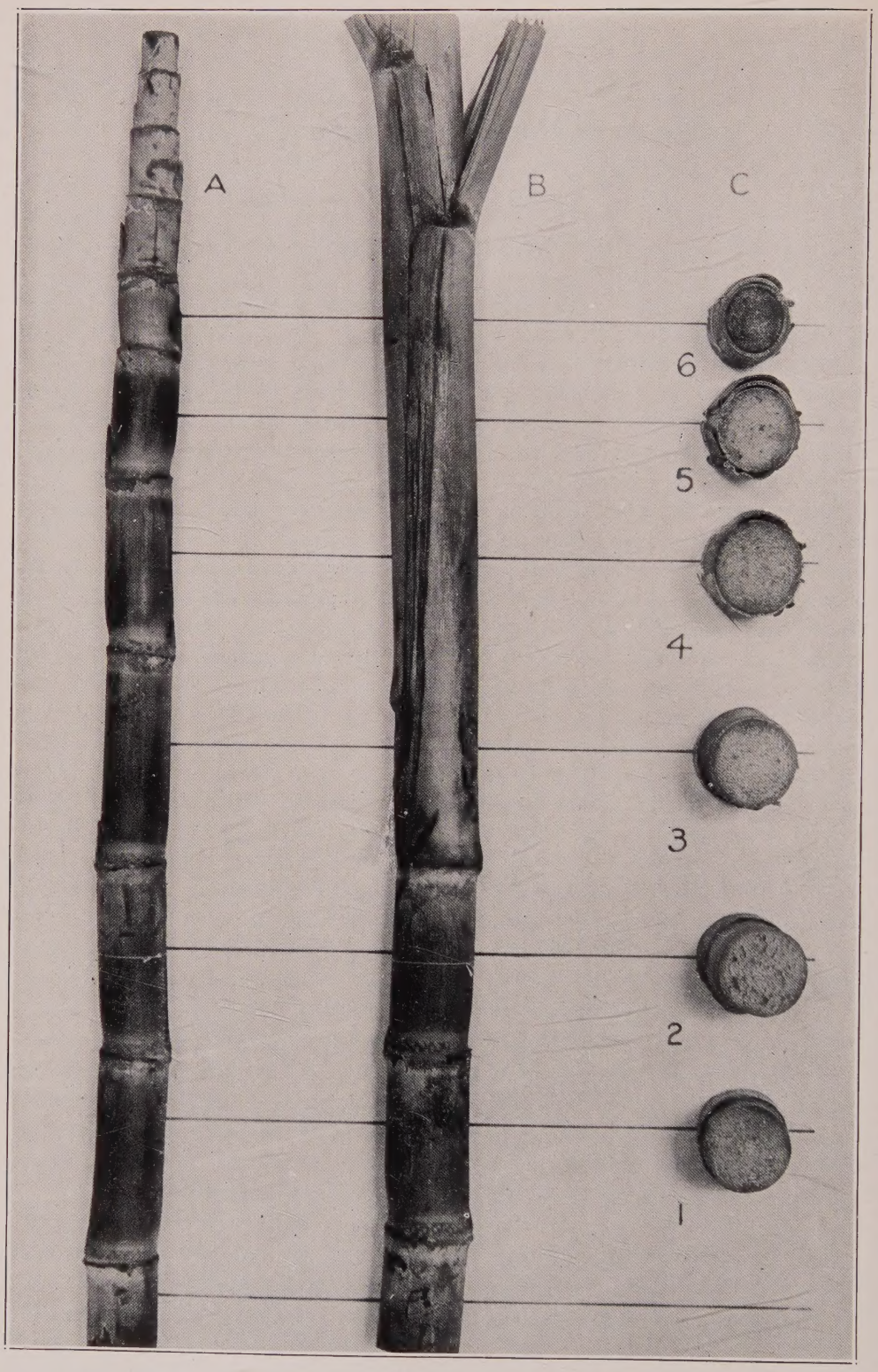
As pointed out in the first article, the greatest difficulty in an investigation of this kind is to determine a reference point that is strictly comparable and capable of duplication with all sticks of cane. Preliminary examination of cane stalks showed that the highest leaf that was tightly wrapped for the full length of its sheath, was attached to a node that had become slightly "weathered". This node having been somewhat exposed to light, had started to assume the color of the main stalk, and was called the highest weathered joint. This particular leaf sheath could be recognized on both burned and unburned cane as the tightly wrapped green leaves did not appear to be affected by the fire.

In the first experiment, designated Series No. 1 in the accompanying tabulations, 29 sticks of H 109 cane grown at the Experiment Station were used. Four sets of determinations were made and these were listed as joints 1, 2, 3 and 4. Joints 1 and 2 were below the center of the highest colored (weathered) joint, and Nos. 3 and 4 were above this point. The samples, including adhering leaves, to conform to actual practice, were chopped very fine and as much juice as possible was obtained under about 1200 pounds pressure per square inch. Analyses were made on both the juice and residual cake and all weights were recorded. Necessary data were also obtained on the main cane stalks.

Apparent purities in Series No. 1 ranged from 80.2 to 56.1 and the recoverable sugar, based on absolute juice gravity purity, from 233 pounds to 83 pounds per ton of joint. The first experiment also indicated that there would be recoverable sugar in the joints above No. 4, and in succeeding experiments the composition of joints 5, 6, and 7 was investigated.

The above results are in the tabulations following and are designated Series 1 to 5, inclusive. The samples, after the first series, were from fields being harvested on outside plantations. The reference point was the same as in the first series, joint No. 3 being cut at the center of the highest weathered joint.

To be able to investigate the composition of the topped material left in the field at the time of harvesting, it was found that a new reference point was needed. When cane is topped "high" the last weathered joint remains on the cane. On investigating cane tops from the bud downward, it is found that just below the bud there are several partly developed joints that are of almost jelly-like con-



A, Cane top with its leaves removed. B, Similar top with the leaves removed to the lowest tightly wrapped leaf. C, Sections made by cuts at the centers of the different internodes.

The most profitable point at which to top depends on the price of sugar and on the cost of cane delivered at the mill. With sugar at 3½ cents a pound top joints are worth saving if they contain 40 pounds of recoverable sugar per ton of joints when loading, transporting and manufacturing costs are included, 60 pounds if all harvesting costs are added, and, 100 pounds if cultivation costs are included.

sistency and which offer practically no resistance to pressure from the thumb nail. There is, however, a recognizable division between the soft joints and one that is firm enough, due to fibrous tissue, to resist moderate pressure. This point was designated as joint No. 1 in the remaining series of experiments beginning with Experiment 6. Investigations were also made to locate this point or a certain joint number in relation to the position of the highest tightly wrapped leaf sheath, so that an external reference point could be established. Information concerning this point is given later.

Experiments 6, 7 and 8 were each run on two series of samples marked A and B. The A series were on whole sticks and the B from tops collected in the same field as the A and as left by the harvesting gang. Joint No. 1 was the first (uppermost) hard joint, and No. 2 the next lower, etc. Subsequent observations showed that in general joint No. 1 corresponded with joint No. 7 in the earlier experiments, No. 2 with No. 6, etc. The average analyses of corresponding joints grouped in this way are so similar that an arithmetical average of the entire 11 experiments is given in the tables.

The results show, that in the lower joints investigated, somewhat over 200 pounds of sugar per ton of joint were recoverable and that the amount is less and less until an average of only 27 pounds per ton is recoverable in the uppermost hard joint. These values, when plotted, do not make a perfect curve, due to the limited number of tests, but the data are sufficiently complete to be of value in determining an approximate optimum point for topping.

J. D. Bond, in a report (2) on a series of five topping experiments at Ewa Plantation Company a few years ago, gives analytical data from the topped material when the cane is "topped low". "Topping low" he defines as "the removal of one seed piece of three eyes with the top". The upper limit of this seed piece is defined as "the removal of the top slightly below the growing point so as not to remove any stalk, and so that the cross section would show fibrovascular matter and no leaf spindle". The latter was defined as "topping high".

Data on the topped material on Bond's five experiments are given below:

Purity (Apparent)	Quality Ratio	Weight Per Cent of Cane as Topped High	Pounds Recoverable Sugar per Ton of Material
1. 41.48	195	4.66	10.2
2. 55.56	40	1.70	50.0
3. 43.72	116	2.82	17.2
4. 51.32	47	3.00	42.6
5. 50.22	52	4.37	38.4
Average	63	3.31	31.5

The sugar recoverable per ton of topped material was calculated from the quality ratio by the writer. The above data, in general, agree closely with those obtained by the writer for the higher cane joints investigated. Bond did not find as great a difference between individual tests, as did the writer, though his differences were large. This is readily accounted for as he was working with samples from several tons of material, while the writer's samples were from 25 to 30

sticks of cane only. The ripeness of the cane and purity of the juice in the main stalk also will cause fluctuations in the recoverable sugar in the upper joints.

The writer, in Experiments 6, 7 and 8, noted for each stalk the number of the joint opposite the center of the highest tightly wrapped leaf sheath. This was to ascertain if a certain joint could be located externally and serve as a guide in harvesting practice. In Experiment 6A the center of the leaf sheath was opposite joint No. 3 in most of the stalks, though there were a few No. 2 and No. 4 joints opposite the center. The same was true in Series 7A, though the uniformity was not quite as good and there were nearly as many second joints as third joints opposite the center. In Series 8A the average indicated that joint No. 2 was opposite the center of the leaf sheath. The above indicates that we appear to have an external reference point from which we can locate approximately any quality of cane material desired. The highest tightly wrapped leaf sheath is partly covered by the sheath of the next lower leaf, but the center or any other desired point can be quite readily located in topping practice.

TABLE A

Apparent Purities of Expressed Juice

	Joint No.						
Series No.	1	2	3	4	5	6	7
1	80 2	73.8	66.6	56.1	...	...	...
2	...	...	69.8	65.2	60.0	53.7	...
3	...	...	56.9	45.6	35.0	29.2	24.9
4	...	...	72.8	67.3	63.0	59 9	54.5
5	...	...	74.6	70.0	62.2	54.8	49.0
Averages	80.2	73.8	68.1	60.8	55.1	49.4	42.8

	Joint No.					
Series No.	6	5	4	3	2	1
6A	...	55.6	43 3	32.7	25.2	17.3
6B	...	65.4	51.6	41.0	28.9	22.4
7A	82.7	77.4	72.8	67.5	59.7	52.3
7B	83.4	74.8	67.5	64.1	56.3	56 5
8A	85.4	81.3	73.6	65.0	56.9	46.0
8B	...	...	...	63.6	...	50.3
Averages	83.8	70.9	61.8	55.7	47.3	40.8
General Averages	81.3	69.5	61.3	55.4	48.1	41.5

TABLE B

Gravity Purities of the Absolute Juice

	Joint No.						
Series No.	1	2	3	4	5	6	7
1	80.6	75.3	69.4	57.9	...	...	...
2	...	...	72.7	68.1	63 1	57.4	...
3	...	...	59.8	50.3	38.8	34.2	30.4
4	...	...	75.4	69.0	64.7	62.3	56.2
5	...	...	74.7	69.8	62.9	55.8	48.0
Averages	80 6	75.3	70.4	63.0	57.4	52.4	44.9

	Joint No.					
Series No.	6	5	4	3	2	1
6A	...	58.4	46.9	37.3	30.5	23.3
6B	...	67.6	54.7	44.7	33.9	27.9
7A	83.3	78.5	74.4	69.6	62.3	55.3
7B	83.9	76 2	69.6	66.4	59.1	59.3
8A	85.6	82.0	75.2	67.2	59.4	49.3
8B	...	...	...	65.9	59.6	53.4
Averages	84.3	72.5	64.2	58.5	50.8	44.8
General Averages	82.0	71 5	63.6	58.1	51.5	44.8

TABLE C

Weight of Upper Joints Per Cent of Cane Weight

	Joint No.						
Series No.	1	2	3	4	5	6	7
1	5.26	4.78	4.40	3.92	...	...	...
2	...	...	2.09	1.97	1.86	1.04	...
3	...	...	1.73	1.68	1.68	1.49	1.23
4	...	...	1.53	1.48	1 34	1.17	1.10
5	...	...	2.35	2.29	2.11	2.04	1.94

	Joint No.					
Series No.	6	5	4	3	2	1
6A	...	2.72	2.62	2.52	2.35	2.18
6B	...	2.49	2.28	1.16	0.60	0 31
7A	2.24	2.22	2.21	2.02	1.85	1.85
7B	1.18	1.07	1.00	0.85	0.61	0.41
8A	2 96	2 81	2.56	2.32	2.03	1.93
8B	...	...	...	2.00	1.07	0.62
Averages	2.79	2.34	2.20	1.79	1.43	1.29

TABLE D

Pounds Commercial Sugar Per Ton of Joint

	Joint No.						
Series No.	1	2	3	4	5	6	7
1	233	191	143	83	...	...	...
2	...	...	145	115	86	62	...
3	...	...	77	37	4	60	00
4	...	...	145	106	85	68	48
5	...	...	161	123	84	53	27

	Joint No.					
Series No.	6	5	4	3	2	1
6A	...	60	23	00	00	00
6B	...	115	50	17	00	00
7A	209	171	139	103	65	45
7B	229	163	116	85	54	56
8A	217	177	129	85	56	29
8B	...	...	...	97	65	41
Averages	212	136	92	65	42	27

TABLE E

Glucose Per Cent in Juice

	Joint No.						
Series No.	1	2	3	4	5	6	7
1	1.05	1.42	1.76	2.10	...	...	...
2	...	...	1.86	1.98	2.08	2.14	...
3	...	...	2.61	2.60	2.41	2.15	1.87
4	...	...	1.47	1.40	1.38	1.22	1.04
5	...	...	1.36	1.51	1.69	1.77	1.61
Averages	1.05	1.42	1.81	1.92	1.89	1.82	1.51

TABLE F

Ash Per Cent in Juice

	Joint No.						
Series No.	1	2	3	4	5	6	7
1	0.82	0.93	1.11	1.33	...	...	..
2	...	...	0.74	0.74	0.79	0.87	...
3	...	...	0.71	0.73	0.86	0.99	0.93
4	...	...	0.82	0.83	0.92	1.02	1.17
5	...	...	0.76	0.78	0.82	0.93	1.03
Averages	0.82	0.93	0.83	0.88	0.85	0.95	1.04

TABLE G

Glucose-Ash Ratio in Juice

	Joint No.						
Series No.	1	2	3	4	5	6	7
1	1.28	1.53	1.59	1.58	...	...	...
2	...	...	2.51	2.68	2.63	2.46	...
3	...	...	3.68	3.56	2.80	2.17	2.01
4	...	...	1.79	1.69	1.50	1.20	0.89
5	...	...	1.79	1.94	2.06	1.90	1.56
Averages	1.28	1.53	2.27	2.29	2.25	1.93	1.49

TABLE H

Sucrose-Ash Ratio in Juice

	Joint No.						
Series No.	1	2	3	4	5	6	7
1	19.29	14.58	9.92	6.16	...	...	...
2	....	....	14.55	12.25	9.70	7.51	...
3	....	....	10.22	6.79	3.91	2.77	2.55
4	....	....	12.80	10.33	7.88	6.06	4.38
5	....	....	15.22	12.36	9.01	6.11	4.26
Averages	19.29	14.58	12.54	9.58	7.63	5.61	3.73

Above has been shown the approximate amounts of recoverable sugar for various upper joints in the cane stalk, and also a method for locating externally where we may expect to find these amounts. The all important question remaining to be settled is the economic one. What does it cost to harvest, transport to the factory, and manufacture the recoverable sugar in these upper joints? After arriving at the costs, the market price of sugar will then determine whether there is a profit or a loss.

It is somewhat of a problem to determine the items which should be included in the total cost of this sugar. The cost of loading and hauling the cane material and also manufacturing and marketing the sugar will have to be included. It will take no more labor or materials to cultivate or cut the cane whether it is topped high or low. However, as our method of payment for these items is based on the weight of cane actually harvested, it appears that part or all of these charges of cultivating and cutting may need to be included.

Three cost tables are given below. The first table includes only loading, hauling, manufacturing and marketing charges. The second table, in addition to these charges, also includes cutting. The third table, in addition to the costs in the second table, includes cultivation. The latter item includes any or all of the following: Irrigation, hoeing, hilling up, cutting back, stripping, animal work, and clearing.

The cost figures are taken from the report of J. S. B. Pratt, Jr., (3) and are averages for four crops, 1925-1929, from twenty-two plantations. They are all on a per-ton-cane basis, with the exception of cost of marketing and containers, which has been assumed by the writer at $10 per ton of sugar. The separate average costs from Mr. Pratt's report follow, together with the three cost tables:

Cultivation, per ton cane	$ 1.26
Cutting, per ton cane	0.33
Loading, per ton cane	0.29
Hauling, per ton cane	0 47
Manufacturing, per ton cane	0.59
Marketing and containers, ton sugar	10.00

FIRST COST TABLE

Cost of Loading, Hauling, Manufacturing and Marketing Sugar from Upper Joints of Cane

	Pounds Recoverable Sugar per Ton Cane							
	20	40	60	80	100	120	140	160
Cost per Ton Cane.$	1.45	$ 1.55	$ 1.65	$ 1.75	$ 1.85	$ 1.95	$ 2.05	$ 2.15
Cost per Lb. Sugar	7.25¢	3.88¢	2.75¢	2.20¢	1.85¢	1.63¢	1.46¢	1.34¢
Cost per Ton Sugar	$145.00	$77.60	$55.00	$44.00	$37.00	$32.60	$29.20	$26.80

SECOND COST TABLE

Cost of Cutting, Loading, Hauling, Manufacturing and Marketing Sugar from Upper Joints of Cane

	Pounds Recoverable Sugar per Ton Cane							
	20	40	60	80	100	120	140	160
Cost per Ton Cane.$	1.78	$ 1.88	$ 1.98	$ 2.08	$ 2.18	$ 2.28	$ 2.38	$ 2.48
Cost per Lb. Sugar	8.9¢	4.7¢	3.3¢	2.6¢	2.2¢	1.9¢	1.7¢	1.55¢
Cost per Ton Sugar	$178 00	$94.00	$66.00	$52.00	$44.00	$38.00	$34.00	$31.00

THIRD COST TABLE

Cost of Cultivation, Harvesting,* Manufacturing and Marketing Sugar from Upper Joints of Cane

	Pounds Recoverable Sugar per Ton Cane							
	20	40	60	80	100	120	140	160
Cost per Ton Cane.$	3.04	$ 3.14	$ 3.24	$ 3.34	$ 3.44	$ 3.54	$ 3.64	$ 3.74
Cost per Lb. Sugar	15.2¢	7.85¢	5.4¢	4.18¢	3.44¢	2.95¢	2.6¢	2.34¢
Cost per Ton Sugar	$304.00	$157.00	$108.00	$83.60	$63.80	$59.00	$52.00	$46.80

Similar cost tables can be worked out by individual plantations, using their own costs. These, together with the prevailing market price of sugar, will readily show the economic point for topping.

If, for example, the market price of sugar is about 3½ cents a pound, according to the first table, material containing slightly over 40 pounds of recoverable sugar per ton of joint is worth saving. On the basis of Table II, the line is at just under 60 pounds per ton, while with all the costs of cultivation included it is at about 100 pounds of sugar per ton.

On the basis of the average of the 11 experiments, Table D, 40 pounds of sugar per ton of cane is at about the second hard joint, 60 pounds at about the third hard joint, and 100 pounds at about the fourth joint.

These experiments for the most part were on ripe canes. Less matured or lower purity cane will have lower recovery figures for corresponding joint numbers.

Each plantation should work out figures for its own conditions. It can be assumed that the juice from topped material will have recoverable sugar if its purity is above the molasses purity of that particular factory. The amount will be shown by application of the s. j. m. formula. Experiments on clarification of last mill low purity juices show that a good increase of purity may be expected from upper joint material. These recoverable values were calculated on the gravity purity of the absolute juice and 37 gravity purity molasses. The above figures are, therefore, believed to be conservative.

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* Includes cutting, loading and hauling.

Cane Breeding in Coimbatore

By U. K. Das

(Note: The information contained in this paper has been obtained from the publications of the Cane Breeding Station at Coimbatore, from the Annual Reports of the Secretary, Sugar Bureau, Pusa, and from personal observations. A list of the relevant publications of the cane breeding station is appended, but in the body of this paper no attempt has been made to definitely cite any reference. Special thanks are due to the Government Sugar Cane Expert, through whose courtesy a number of illustrations appearing herein were secured.)

Introduction

The cane breeding station at Coimbatore was founded in 1912 by the Government of India, in response to a demand to help the native sugar industry in the face of extreme foreign competition. This station was first sanctioned as a temporary measure, but as a result of its excellent work, extending over a dozen of years, it was made permanent in 1925.

The main and immediate object of the new station was to breed improved varieties of cane for sub-tropical North India,* which grows over 80 per cent of India's total. Coimbatore, which is in the tropics and at a distance of about 2,000 miles from North India, was selected as the site of the station because, situated at the foot of the Nilgiri Hills at an elevation of about 1,000 feet, it enjoys a very mild climate and the canes around were known to flower freely and profusely, whereas in North India flowering of cane was almost unknown. In these respects Coimbatore is like Malang, where most of the breeding operations of Java are carried on at present.

The North Indian Cane Belt

The sugar belt in North India comprises the provinces of the Punjab, the United Provinces of Agra and Oudh, and Behar. The extreme growing conditions are met with in the Punjab, where the summers are unusually hot and dry and the winters very severe, with occasional frosts. The growing season is hardly eight months. From the Punjab as we move southeast toward the United Provinces and Behar, the climate gets milder and the growing season longer. Sugar cane has been cultivated in these parts from a very ancient time and the varieties that survive today are usually of the thin to medium type, with fair sucrose. The problem, then, before the new station was to breed cane varieties that would do well under the trying conditions of North India and yield more sugar than the trusted and tested varieties of the old.

* Since 1926, the scope of the station has been extended, and the breeding of thick canes for tropical India has been taken in hand.

Raising of Seedlings—Breeding Material

The first efforts of the station appear to have been the collection of most of the important North Indian canes, and the collection from within India or by importation from abroad of a large number of thick tropical canes; for it was early recognized that the improved varieties for North India would most likely be crosses between the thick tropical and thin Indian canes. Thus as early as 1915, there were growing at the station 130 thick and 112 thin varieties of cane, besides the newly bred seedlings. As sugar cane breeding is still largely a method of "try and discard," a large assortment of breeding material is the *sine qua non* of rapid progress.

Fig. 1. A view of the cane breeding station, Coimbatore, India.

At the present time the breeding material at the station consists of several varieties of wild canes (*Sacch. spontaneum*), all the different groups of Indian canes, a large number of tropical varieties, and the selected Coimbatore canes.

Flowering

In Coimbatore, the flowering season extends from the first week in October to January. This season coincides with the east monsoon and as a rule there are some heavy showers and wind. Generally, the thick tropical varieties flower first, followed by the cross-bred seedlings and the thin Indian canes. Some of the spontaneums are in flower almost throughout the season. Not all varieties flower every year. Also, some that flower this year may not do so in the next.

Considerable difficulty was experienced in the beginning of this station in the matter of flowering, for though the local thick canes flowered freely, the imported North Indian canes refused to do so. Some of these canes were induced to flower by planting them on wet clay soil, and in 1915 as many as 36 thin varieties flowered at the station and most of them for the first time on record. Of the five groups of Indian canes, only two, namely, the Saretha and the Pansahi, have flowered freely so far.

The other three groups, namely, the Nargori, the Mungo and Sunnabile, are

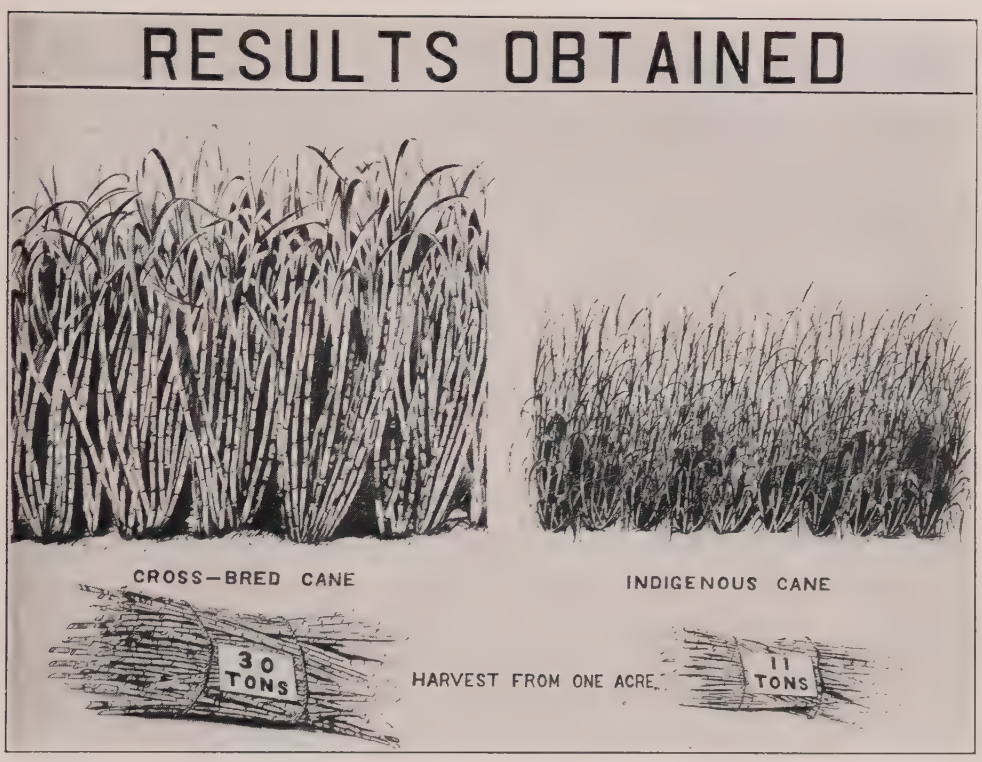


Fig. 2. The benefit to be derived from the creation of new varieties by scientific cane breeding is exemplified in this illustration. By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

extremely erratic though producing occasional flowers. Even when a cane of any of these three varieties flowers, the essential organs are generally found to be undeveloped. From the breeding point of view, these three varieties are of great importance and success in inducing them to flower is likely to be of great consequence. Towards this end the station is, at present, working on several lines, such as (1) manurial treatments, (2) spraying the cane leaves with chemical solutions, (3) planting the recalcitrant varieties in different altitudes.

Time of Flowering

Next in importance to flowering is the time of flowering. As elsewhere, the cane breeding station has had to give up many valuable crosses simply because the two varieties would not flower at the same time. This is a problem that faces the cane breeder in every country and one that needs a speedy solution. The station has in the past achieved some measure of success by planting the varieties in different seasons, but the gain in time has not been considerable. A great deal of attention is being concentrated on this problem at present and the solution is being sought to two ways, (1) directly, that is, by hastening or retarding the time of flowering by such means as smoking of cane, cutting off a portion of daylight, application of certain chemical fertilizers, (2) indirectly, by storing cane pollen in

Fig. 3. A view of the smoking shed in the field. Here standing canes were smoked for weeks to promote early tasseling.

Fig. 4. Tile potting of selected stalks to induce root development at the nodes, so that these canes could later be cut off and isolated from the field when tassels emerged.

a viable condition for a certain length of time. As a result of experiments, it has been found possible to preserve cane pollen for 12 days in an atmosphere of CO_2.

Use as Male or Female

Usually the varieties that do not give pollen freely or do not give it at all are used as mothers and the prolific pollen givers as fathers. But at times, when it is intended to use a good pollen-giving variety as mother, the pollination is done early in the morning before the variety starts shedding its own pollen.

Pollen Fertility

The iodine test of pollen was used at first. It was, however, discovered that a simpler and more practical test would be the relative anthesis of a tassel because anthers fully dehisced invariably contained large numbers of well-developed pollen. None of these methods were perfecty satisfactory, as none gave any definite idea as to whether the pollens that had starch grains in them were actually viable at the time of cross-pollination. Artificial germination of pollen was first secured with some amount of success, by using the stigmas of "Datura fastuosa." In recent years considerable success has been attained in germinating pollen in an artificial culture of sugar solution.

Pistil Fertility

A great deal of useless labor can be saved if the fertility of a tassel can be determined before its use as a mother. The iodine reaction of the style was depended

upon for a long time, but more recent experiments have shown that while this iodine test applies satisfactorily to the thin Indian canes, it fails with the tropical canes, in the case of which the actual germination test is the only reliable one.

Controlling Dehiscence of Anthers

Sometimes it is necessary to effect a cross between two varieties located at a distance of days from each other. The difficulty of mating them has been solved by controlling the dehiscence of anthers of the male parent by placing it in a humid chamber and transporting it over the distance.

In this way it has been possible to control dehiscence for as many as 10 days. The same method has also been used to good advantage in crosses like *Sacch. spont.* x Karun (a tropical cane), a cross which is ordinarily rather difficult because of the free dehiscence and self-pollination of the spontaneum before the tropical cane starts to dehisce.

Fig. 5. A view in the breeding ground. Arrows isolated from the field after adventitious roots had been developed by layering the cane. By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

Controlling Male Fertility

A great advance towards scientific cane breeding would be made if it were possible to render a tassel male sterile by artificial means. Towards this end, the Coimbatore station has been experimenting for some time past by growing cane tassels in various chemical solutions or under low temperature conditions. So far these experiments have not succeeded.

Fig. 6. First Ground Nursery. Seedlings are transplanted from the germinating pans directly to the fields. By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

Crossing Technique

The first seedlings obtained at this station were from tassels collected in the field and designated as general crosses. In these crosses only the mother parent is known with any amount of certainty. Later on as needs developed for more exact knowledge of both the parents several methods were tried from time to time, the chief among which were (1) emasculation, (2) bagging together arrows grown in adjacent plots, (3) pollinating with male tassels brought from elsewhere and kept in water, (4) dusting the mother arrows with dehisced anthers or collected pollen, (5) artificial rooting method.

The emasculation method was given up after two years of trial, because it involved great practical difficulties owing to the delicate nature and minuteness of the florets.

The adjacent plot method, as well as the method of dusting the mother arrow with collected pollen, did not prove quite satisfactory owing to obvious reasons, and both the methods were slowly abandoned. The bagging of arrows was found to be harmful to germinating and seed setting; this practice was given up in 1916. Up to 1925, the method in general use was to keep the mother tassel growing in the field and pollinate it for a period of 4 to 5 days by placing over it a cut stalk of the pollinating parent, which was kept in a bottle of water. A fresh tassel was brought in every day.

The artificial rooting method was evolved in 1925. This method consists of inducing the flowering stalk to develop some secondary roots from root bands and then isolating the stalk from the field. As soon as the canes show indication of

tasseling by the sudden elongation of the stalks and simultaneous shortening of the leaves, a ball of soil is wrapped round one or two joints of the cane at a distance of several feet from the top of the arrow. The soil is kept moist by occasional watering. At the end of two or three weeks roots have developed sufficiently to be able to feed the part of the stalk above the treated joints. The stalks are then cut and taken to the hybridization sheds. Here they are placed in pots containing soil and the arrows continue developing without any setback. Cross pollination is made and the seed setting is in no way affected. This is undoubtedly a great improvement on the old method of breeding for it ensures the complete segregation of tassels from which results certainty as to the parentage of seedlings. This method has another sphere of great usefulness in making it comparatively easy to self cane varieties. The method suffers, however, from a slight disadvantage in large-scale operations in that it entails a great amount of labor and much preliminary work in the fields.

For large-scale operations, the method in general use consists of collecting spikelets of male flowers early in the morning before the anthers start dehiscing. These spikelets are then carried to the female tassel growing in the field and the pollen dusted on at the proper time. This method is very convenient and successful.

Collection of Seeds for Planting

As soon as the tassels get ripe, which takes about three to four weeks from the time of pollination and fuzz begins to blow, the tassels are cut and gathered in paper packets. The bags are kept in a cool and dry place for a few days, or at times dried for a day or two in the open, after which the fuzz is separated and planted in pans. Recent experiments have shown that the fuzz can be dried as effectively by putting it in an oven at 40° C. for a few hours.

The seeds are planted in earthen pots. The first pots used were about 12″ wide and 3″ deep; later on bigger pots, with a bottom 9″ wide and a depth of 6″ were substituted. At present the pans in use are cylindrical in shape, about 12″ wide and 6″ deep. The mixture in the pot consists of equal parts of rotten horse manure and fine river sand. Before using in the pots, the horse manure is freed of weed seeds by forcing them to grow and picking out the weeds. This method was originally borrowed from Java and has been in practice for all these years.

The fuzz is spread on the pan and watered with a rose from a height of about 3 feet, which beats the fuzz a little into the mixture and makes fine particles of sand adhere to the seeds. The pans are placed on the ground or on raised bamboo platforms, in the open air. These pans are left exposed outside even at night, except when rain comes, and they are covered.

The pans are watered three to four times a day so that the fluff is always moist. First germination takes place in 6 to 7 days; pans not showing any germination after two or three weeks are discarded.

The germinated pans are kept in full sunlight; and as the seedlings begin to produce roots which enable them to draw moisture from below the surface, the watering is reduced to once or twice a day. There is not much damping off in the

seed pans, although no chemicals are used to prevent the growth of algae and fungi.

The seedlings grow to a height of 2 to 3 inches in these pans before they are transplanted. At times when a pan is very much crowded, seedlings are picked off into a separate pan at an earlier stage. At the time of transplanting, the weak and very poorly growing seedlings are generally left behind. At times, as in 1923-24, as high as 30 per cent of seedlings are thus discarded.

First Ground Nursery

It was the custom in former years to transplant the young seedlings into individual pots. These pots were about a foot high and nine inches across, and contained a mixture of fine red earth, ordinary earth, cattle manure, and leaf mould in equal proportion. The pots were watered with a rose, or buried flush with the soil in trenches into which water was run.

In 1925, the pots were dispensed with, and now the seedlings are transplanted directly in the ground in what is called "The First Ground Nursery." For this purpose fields with a fair admixture of sand and soil are chosen. The soil is carefully prepared so as to obtain a fine surface tilth. Small raised beds are made of about 2′ wide, 4″ deep, and any convenient length, by taking soil from between the adjacent plots. This space in between is then used as a path to facilitate inspection of growing seedlings. Into these beds the young seedlings are transplanted from the pans, usually with a ball of soil around the roots. The plants are placed along the width of the row at a distance of 1″ from each other, the rows being 2½″ apart. The beds are watered immediately before and after transplanting. The plants are watered twice or more a day with a garden hose till they are well established, thereafter the water is supplied by irrigation channels dug on either side of the beds. When the plants are about 4″ high the rows are gently hilled up by drawing the soil from between them by means of a bamboo fork.

This technique of planting in the first ground nursery was slightly modified in 1928. The rows are now made 1′ apart and the plants put at a distance of 6″ to 8″ from each other. Furthermore, V-shaped sand veins are run along the length of the bed across the middle of the rows. Similar veins are run along the width of the bed midway between the rows. Irrigation channels are made on either side of the bed right from the beginning, and even at the earliest stages instead of watering with a can the water is run into the channels to be distributed to the plants along the sand veins. When the plants are a couple of inches high and well started, the lateral sand veins are opened and these, then, serve as small irrigation and drain ditches. These modifications have materially increased the vigor and health of the seedlings.

The great advantages of this method are: (1) saving in the cost of pots and the labor involved in using them, (2) more efficient and uniform distribution of water, (3) less chances of injuring the delicate little plants by applying water with a rose can, (4) better drainage, should that be necessary.

In this nursery the plants grow for two to three months. When they are about 1′ to 2′ high they are transplanted to the second ground nursery. In the past no

vigorous selection was made at this stage, only the very sickly looking plants being left behind. But last year this very preliminary selection eliminated almost 80,000 out of 100,000 seedlings raised.

The Second Ground Nursery

The land for the second ground nursery is prepared as carefully as the first. Plots ten feet wide and any convenient length are laid out, each plot having on one side an irrigation ditch and on another a drain. The plants are carefully transferred from the first ground nursery, usually with a ball of earth around them, and planted in rows at about 18″ from each other. Immediately after planting a copious irrigation is given. Henceforward, weekly irrigation is the rule. It becomes necessary sometimes to run a solution of tar emulsion into the fields together with irrigation water to prevent white ants, etc. Usually this transplanting into the second ground nursery is made in the months of May or June. Here they stay for eight to nine months, at the end of which time the seedlings are selected and analyzed and those that are retained are planted by sets into the final test plot.

Fig. 7. A small animal-driven mill for juice sampling.

Final Test Plot

Here the selected seedlings grow for a full year, at the end of which they are analyzed and rigorously selected, keeping in mind the locality for which they are intended. As outside rows are likely to grow better, due to their advantageous position, it is the custom to plant them with some standard cane.

The selected seedlings go to another field of a different soil type, and the following year to another, before they are finally sent out to outside stations for local variety trials. The purpose of planting them to different soil types is to get an idea of the possibility of a seedling under different conditions. For often it happens, as it did with Co. 281, that a seedling that grows poorly in one type of soil, thrives luxuriously in another. Thus it takes almost four years from the time the seedlings germinate to the time some of them are sent out as selected seedlings. In

the future it is proposed to shorten this period of testing by simultaneously planting the selected seedlings into three soil types.

Selection of Canes

In the earlier years selection was based primarily on sucrose. But it was soon found that without vigor and tonnage, mere sucrose was of no value. Also that in a group of seedlings from the same parents the ones that had high sucrose had invariably less vigor and growth. In other words, detailed study revealed the presence of an inverse relationship between vigor and richness of juice.

Nowadays canes are selected mostly on vigor and tonnage (actual weights are never taken, tonnage being judged by the eye alone), certain types such as the Punjab type and the Behar type signifying that for each locality certain characters must be given preference. Consideration of sucrose assumes a place of secondary importance, meaning thereby that while at times canes medium in sucrose may be selected for their vigor, sometimes canes very rich in sucrose are discarded because of lack of vigor. The cane that strikes the eye most is the cane that stands the best chance of being picked up. Also, to be selected, canes must have a straight habit, and, generally, early maturity. Recently importance is beginning to be placed on root development in selections, for it is felt that for each soil there is a definite type of root development that is likely to prove most satisfactory. Canes are also bred for disease resistance, but Coimbatore being more or less free of diseases, this point does not largely enter into consideration in selections made at the station. Only when the canes are sent out can this point be studied.

There is a great difference in the type of cane suitable for the different provinces, thus affording a greater choice.

Cane for the Punjab must be (1) resistant to frost, (2) early maturing, (3) resistant to drought or water-logging, (4) resistant to disease.

For Behar or U. P. the canes must be of medium type, able to benefit by irrigation or well distributed rainfall, (2) they may take a longer time to mature than those for the Punjab, (3) they must be disease resistant, especially to Mosaic.

The preliminary analysis is done when the cane is not fully ripe. In this analysis, especially when the canes are in the second ground nursery, the practice is to take only the portion of the cane up to the last dead leaf. For experiments have shown that this part of the cane gives a very good idea of the sucrose in the fully mature crop. The very first analysis may take only the Brix which is read in the field from the refractometer, the juice being obtained with a specially devised syringe. Sometimes small samples are run through a three-roller animal-driven mill, and Brix, sucrose, purity determined. Usually only those seedlings that come up to certain standards in the first analysis are analyzed the second time. The preliminary samples consist of two stalks only; larger samples are taken for full analysis. They are all random samples—a laborer goes through the field and selects the required number of average good stalks of the particular cane.

An idea of the rigorousness of selection can be gained from the statement of the year 1923-24; out of 130,000 seedlings raised, about 100,000 were planted in the first nursery, 80,000 in the second nursery, and only 10,000 in the final test plot.

And out of those 10,000 probably not more than 5 will receive the permanent number. Looking at it from another angle, roughly we may say, there have been raised up to date in Coimbatore 800,000 seedlings out of which only about 300, or 1 in 3,000, have received permanent numbers, and only about 10, or 1 in 80,000 has proved of commercial value.

Nomenclature—Distribution

Formerly the canes selected from the second ground nursery were given an "M" number, M standing for Madras, in which presidency the Coimbatore station is situated. Owing to confusion with M for Mauritius, the present practice is to name such seedlings "G," such as G1, G2, etc. The canes that are to be sent out to the provinces are given a "Co." number. No attempt is made to indicate as to what year they were raised.

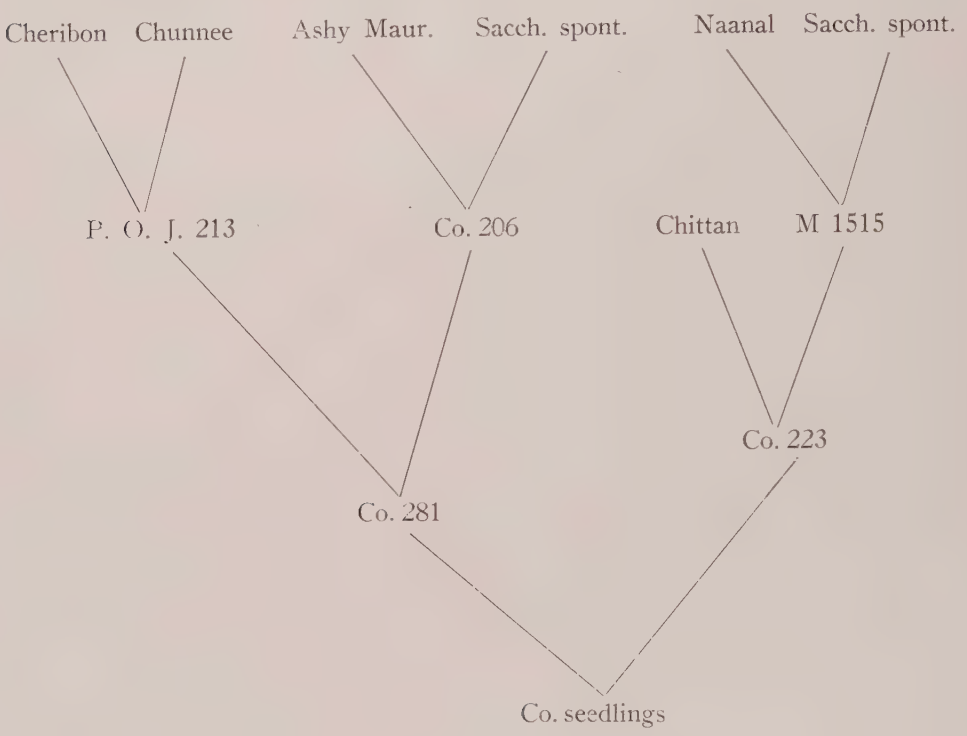
The cane station started work in 1913 and the first batch of seedlings was sent out to different places in India in 1918. In earlier years it was felt that a selected seedling should be tried several seasons to determine its consistency before being sent out. Experience soon proved that the variation in the seasons from year to year was naturally so great that the desired information as to consistency could not be gained even after several years of trial. Nowadays as soon as a seedling is noted promising and selected, it is sent out, and, as has been stated, it is proposed to further expedite this distribution.

Inheritance Studies

For some time past, the Coimbatore station has been devoting considerable attention to studies in inheritance, mainly for the purpose of obtaining information that will help the creation of new varieties. So far the studies have included (1) general field characters, (2) morphological characters of the leaf and cane, (3) root characters, (4) juice, (5) susceptibility to disease.

The inconsistency of data, probably due to the lack of sufficient material, makes it impossible to be definite on any point. But even the indications offer helpful suggestions, and it is claimed that such studies have already been of value in producing, by suitable mating, promising seedlings for sub-tropical India.

A Typical Genealogical Tree of the More Recent Coimbatore Seedlings



Some Important Coimbatore Canes

(An excellent description of some of these canes appeared in *Agr. Jour. Ind.* Vol. 23, No. 1, 1928.)

Co. 205 (Vellai x Sacch. Spont.):

Thin cane, glaucous green color, grooveless, straight joints, hard rind.

Nowadays the standard cane in the Punjab. Hardy, vigorous, late maturing. "Resists frost, drought, water-logging and is specially suitable to unfavorable conditions of growth because of its remarkable root system. Susceptible to Mosaic and Pyrilla attack."

Co. 210 (P. O. J. 213 x Unknown), Field collected:

Brownish purple, thin to medium cane.

Fairly hardy, best ratooner of all the important Co. seedlings. Fairly resistant, more than 213, to drought, water-logging and frost. Early maturity. Grown extensively in Behar.

Co. 213 (P. O. J. 213 x Kansar):

Erect cane of medium thickness, brownish or pinkish yellow color.

Fig. 8. Co. 205—the poor man's cane. This remarkable cane will stand both drought and water-logging. Here is seen a field of Co. 205—5 months under water and giving about 18° Brix at harvest. By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

Fig. 9. A good field of Co. 213 in the provinces. By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

Fig. 10. Benefits of Breeding. Compare the stand of Co. 213 with that of the old standard cane Hemja (Co. 213 on the left, Hemja on the right). By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

The most widely cultivated Co. seedling, the standard cane in Behar and U. Provinces. Good habit, great vigor. Susceptible to Mosaic but not badly affected by it.

Co. 214 (Str. Maur. x M 4600) (M 4600 = Sarctha x Spont.):

Thin cane, greenish yellow in color. Fair vigor, matures earlier than any other Co. cane, with a good quality of juice. Highly resistant to Mosaic. Preferred by mills as a cane for early season work.

Co. 281 (P. O. J. 213 x Co. 206) (Co. 206 = Ashy Maur. x Spont.):

A thin to medium cane, pinkish to brownish in color.

Good straight habit, vigorous grower. Deep root system, resistant to drought. Good juice. This cane is giving excellent results on the red exhausted soils in Cuba, but has no commercial importance in India.

Co. 285 (Green sport x Unknown) Field Cross:

Thin to medium cane, greenish yellow stalks. This cane is proving better than Co. 205 in the Punjab. It is more vigorous than Co. 205 and is less affected by diseases.

Co. 290 (Co. 221 x D 74):

Medium thick cane, brownish to pinkish yellow color, heavily waxed, good stooler, easy stripper.

This is, in my opinion, the best of all the Coimbatore seedlings. It is early maturing, has good juice, gives excellent yields and is commercially resistant to major cane diseases. It is, however, a cane that needs attention and good culture. I counted 196 well-formed stalks of this cane in a 40′ row in Coimbatore. The average stalk was about 1″ in diameter and 9′ to 10′ high, one year's growth. The neighboring row of D 74 had only 78 stalks, and less height. It is believed that this cane will soon replace Co. 213 in most parts of U. P. and Behar.

Fig. 11. Co. 290—5 months old. In the opinion of many, this is the best Coimbatore seedling. It has excellent vigor and good juice.

Lines of Work

The cane breeding station was started mainly for producing improved varieties of cane that would yield more and consequently make cane growing in India a profitable business. In the *Annals of Applied Biology*, 1915, Dr. Barber, the Government sugar cane expert, wrote:

> In all cases it will be our aim to cross good North Indian canes with good South Indian or exotics and in the case of the former the importance is recognized of choosing one parent which is largely grown and valued in the particular part of India to which it is intended to send the resulting seedlings for trial.

Unfortunately, however, this aim could not so easily be realized, for it was found that most of the North Indian canes, except the members of the Saretha group, refused to flower. Even when one or two of them did flower, they were found to be sterile. Attention was, therefore, turned to obtaining crosses between members of the Saretha group and the tropical canes, or the wild Saccharums and

the thin Indian or the tropical canes. The belief was more or less current at the time that the thin Indian canes might have originated from the wild Saccharums and, therefore, it was felt that a cross between a thick cane and a wild cane might give thin canes of the North Indian type. Thus in 1913, for the first time in history of cane breeding, large numbers of seedlings were obtained from a cross Vellai x S. Narenga. The seedlings, however, did not come up to expectations and neither could they be used in future crosses as they were infertile. But crosses between Vellai x S. Spont. proved more successful, and of this cross we have the new seedling Co. 205, which has become the standard cane of the Punjab. Attention was next drawn to the newer Java seedlings; these seedlings were known to combine the Indian Chunnee, the Java Cheribon and sometimes the wild blood. This line of work at once showed promise and it still continues to receive prominent attention. From this line of work has been evolved many of the famous Co. seedlings.

As has been the experience in every country, after the first big step in improvement has been made, further progress becomes exceedingly slow. It is easy to

Fig. 12. Contrary to usual experience, selfing is here seen to induce vigor. On the left Co. 205 and on the right a self of Co. 205 (M 58231), both of same age. Note the difference.

find a cane that is better than the old standard, but it is hard to find another cane that will beat this new cane by a fair margin. It may be either due to the fact that the new standard is high, or, as Professor Harrison declared in his presidential address to the planters of British Guiana:

In the earlier years working with natural varieties of sugar cane, several kinds of high promise are invariably obtained; in later years, when the mass of material for parental purposes has rapidly and enormously increased, the production of really good varieties appears to

be increasingly difficult. It looks as though the good results arose from the unravelling of the complex ancestry of the natural varieties, while similar results from the retangling of the new strains thus obtained are comparatively rare and very elusive. (*Agr. News*, Vol. XVII, No. 428, Sept., 1918.)

Very recently there has come a new line of research and one in which this sugar station stands alone in the world, namely, breeding improved canes by selfing. Both Co. 205 and Co. 214 are admirable canes, but both of them have some defects. Co. 205, for instance, gives impure juice and is late maturing; also it is subject to Mosaic.

Many attempts to repeat the cross proved disappointing. Co. 205 was, therefore, selfed. In 1927, 2,000 of such seedlings were raised, and of these one cane, Co. 229, was better than Co. 205 in respect to juice, but it lacked the vigor of Co. 205. Next year, 15,000 selfed seedlings were raised from Co. 229, and one of these (M 58231) appears to be the type wanted. An accompanying illustration (Fig. 12) shows Co. 205 and M 58231. The greater vigor of M 58231 will be noted. The same success appears to have been obtained by selfing Co. 214.

Another line of work being followed at present is to repeat the several promising crosses, raise a very large number of seedlings, thus to exploit the full possibilities of a particular cross. The breeding program at the station at present, therefore, consists of (1) raising a small number of seedlings from a few crosses, and to study type of seedlings obtained, (2) raising a very large number of seedlings from one or two very promising crosses, and to obtain from among the big lot canes of economic importance. Thus in 1928-1929, the bulk of the seedlings were from two crosses, namely: Co. 213 x Co. 214 and Co. 213 x Co. 281.

Attention is also being paid in recent times to creating seedlings which will have a certain type of root system that will naturally make them suitable to certain soil types. For deeper root system, the infusion of wild Saccharum blood has been found helpful.

For breeding disease resistant canes, either the wild Saccharum is used or canes that are known to be immune to the particular disease.

Very recently there have been attempts to raise canes for populating what are considered waste lands. The Indo-Gangetic plain has thousands of acres of land that will not grow anything but wild grasses. It is felt that if a seedling could be raised that would be as hardy and vigorous as the grasses but at the same time possess a certain amount of sucrose, say about 10 per cent, those lands might yet be made to produce something of economic value. There are now growing at the test plots of the station some thin seedlings which are considered quite promising, for this particular purpose.

Conclusion

It is estimated that the present area under the Coimbatore seedlings in subtropical India is well over 100,000 acres and that this represents an annual increased profit to the growers of nearly 100 lakhs of rupees (about $3,500,000) against an annual expense of about half a lakh on the station. These figures gain in significance when it is realized that things move slowly in a country like India. The Coimbatore station furnishes another excellent example of what can be

achieved in agriculture with the help of science. This station promises some day to become the savior of the dying sugar industry of India.

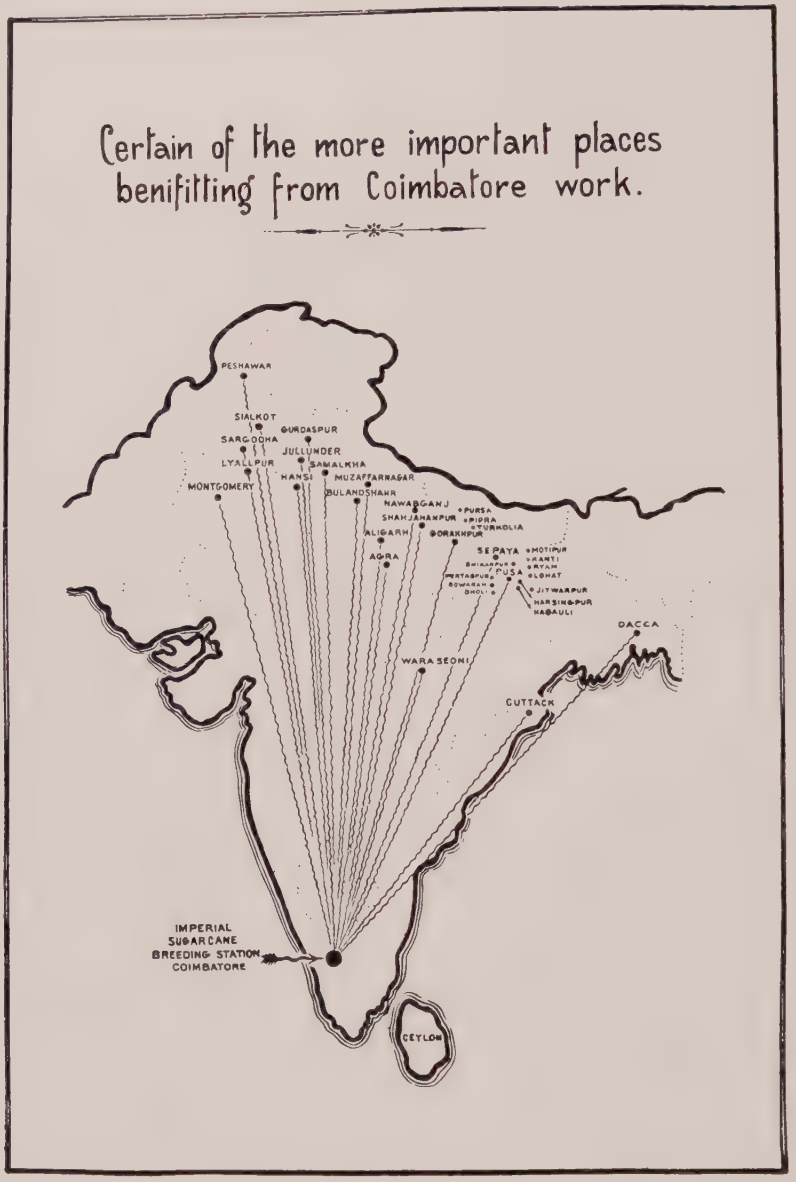


Fig. 13. The whole of India benefits from the work done in Coimbatore. The increased profit to the growers due to the introduction of new varieties runs into hundreds of thousands of dollars. By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

LIST OF PUBLICATIONS FROM THE OFFICE OF THE GOVERNMENT SUGAR CANE EXPERT, COIMBATORE, AS OF DECEMBER, 1929

Serial Number	Title of Publication	Author	Reference
1.	Sugar and the sugar cane.	C. A. Barber	Agr. Jour. India, Vol. X, part 3, page 237. 1915.
2.	Some difficulties in the improvement of Indian sugar canes.	C. A. Barber	The Annals of Applied Biology, Vol. I, page 211. 1915.
3.	Studies in Indian Sugar canes, No. 1, Punjab Canes.	C. A. Barber	Mem. Dept. Agr. India, Bot. Ser. Vol. VII, page 1. 1915.
4.	Studies in Indian Sugar canes, No. 2, Sugar cane seedlings including some correlations between morphological characters and sucrose in juice.	C. A. Barber	Mem. Dept. Agri. India, Bot. Ser. Vol. VIII, No. 3, page 103. 1916.
5.	The classification of indigenous Indian Canes.	C. A. Barber	Agri. Jour. India, Vol. XI, part 4, page 371. 1916.
6.	A study of the arrowing (flowering) in the sugar cane with special reference to selfing and crossing operations.	T. S. Venkatraman	Agri. Jour. India, Spl. Ind. Sci. Cong., page 97. 1917.
7.	Study of the sucrose variations in successive cane joints as they attain maturity with special reference to the death of the leaves.	T. S. Venkatraman and K. Krishnamurti Row	Agri. Jour. India, Spe. Ind. Sci. Cong. No. 1917, page 117.
8.	Testing new cane seedlings in North India.	C. A. Barber	Agri. Jour. India, Vol. XIII, part 2, page 243. 1918.
9.	Studies in Indian Sugar Canes, No. 3, The Classification of Indian canes with special reference to the Saretha and Sunnabile groups.	C. A. Barber	Mem. Dept. Agr. India, Bot. Ser. Vol. IX, No. 4. 1917.
10.	Studies in Indian Sugar Canes, No. 4; Tillering or underground branching.	C. A. Barber	Mem. Dept. Agri. India, Bot. Ser. Vol. X, No. 2. 1918.
11.	The effect of salinity on the growth and composition of sugar cane varieties.	K. Krishnamurti Row	Agri. Jour. India, Spl. Ind. Sci. Cong. No. 1919, page 476.
12.	Studies in Indian sugar canes, No. 5; On testing the suitability of sugar cane varieties for different localities by a system of measurements. Periodicity in the growth of the sugar canes.	C. A. Barber	Mem. Dept. Agri. India, Bot. Ser. Vol. X, No. 3. 1919.

Serial Number	Title of Publication	Author	Reference
13.	Progress of the Sugar cane industry in India during the years 1916 and 1917.	C. A. Barber	Pusa Bulletin No. 83, 1919.
14.	A preliminary note on the behaviour in North India of the first batch of sugar cane seedlings distributed from the Sugar Cane Station, Coimbatore.	T. S. Venkatraman	Pusa Bulletin No. 94, 1920.
15.	A few hints on labelling in Experimental Stations.	T. S. Venkatraman	Agri. Jour. India, Vol. XV, part 1, page 45. 1920.
16.	Packing seed sugar canes for transport.	T. S. Venkatraman	Agri. Jour. India, Vol. XV, part II, page 174. 1920.
17.	Habit in Sugar canes.	U. Vittal Rao	Agri. Jour. India, Vol. XV, part IV, page 418. 1920.
18.	The care and treatment of new sugar cane importations.	T. S. Venkatraman and R. Thomas	Agri. Jour. India, Vol. XVI, part 1, page 24. 1921.
19.	A simple pollinating apparatus.	T. S. Venkatraman	Agri. Jour. India, Vol. XVI, part 2, page 203. 1921.
20.	Preservation of cut canes.	K. Krishnamurti Rao.	Mad. Agri. Dept. Year Book, 1920-21, page 89.
21.	Irrigation water for sugar cane cultivation.	K. Krishnamurti Rao.	Mad. Agr. Dept. Year Book, 1920-21, page 97.
22.	Germination and preservation of sugar cane pollen.	T. S. Venkatraman	Agri. Jour. India, Vol. XVII, part 2, page 127. 1922.
23.	Sugar cane root systems; Studies in development and anatomy.	T. S. Venkatraman and R. Thomas	Agri. Jour. India, Vol. XVII, part 4, page 381. 1922.
24.	A cheap and efficient method of propping sugar canes.	T. S. Venkatraman	Agri. Jour. India, Vol. XVII, part 4, page 416. 1922.
25.	Some suggestions to the grower of sugar cane.	T. S. Venkatraman	Mad. Agri. Dept. Villagers' Calendar, 1922-23, page 42.
26.	Sugar cane breeding in India.	T. S. Venkatraman	Imp. Bot. Conference, London, 1924, Rept. of Proceedings, pp. 57, 121.
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Serial Number	Title of Publication	Author	Reference
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29.	Sugar cane Breeding in India—Hybridization to testing.	T. S. Venkatraman	Agri. Jour. India, Vol. XX, part 3, page 173. 1925.
30.	Studies in sugar cane germination.	T. S. Venkatraman	Agri. Jour. India, Vol. XXI, part 2, page 101. 1926.
31.	Sugar cane Breeding Technique—Isolation of live arrows from undesired pollen through artificial rooting of canes.	T. S. Venkatraman and R. Thomas	Agri. Jour. India, Vol. XXI, part 3, page 203. 1926.
32.	Sugar cane Breeding—Indications of inheritance.	T. S. Venkatraman	Mem. Dept. Agri. India, Bot. Ser. Vol. XIV, No. 3, 1927, page 113.
33.	Breeding improved sugar canes for the Punjab.	T. S. Venkatraman	Agri. Jour. India, Vol. XXII, part 4, page 293. 1927.
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36.	A method of studying the roots of sugar cane.	R. Thomas	Agri. Jour. India, Vol. XXII, part 2, page 138. 1927.
37.	An Improved Pitting Crowbar.	L. K. Narayanan	Agri. Jour. India, Vol. XXII, part 5, page 383. 1927.
38.	Coimbatore seedling canes. Co. 205, 210, 213, 214 and 223 described and illustrated.	T. S. Venkatraman and U. Vittal Rao	Agri. Jour. India, Vol. XXIII, part 1, page 28. 1928.
39.	A Leaf Adaptation conducive to Mosaic resistance in the sugar cane.	T. S. Venkatraman and R. Thomas	Agri. Jour. India, Vol. XXIII, part 1, page 56. 1928.
40.	The Indian Sugar Bowl and Agricultural Research in connection therewith.	T. S. Venkatraman	Pres. Address, Agri. Sec. Indian Sci. Congress, 1928. Agri. Jour. India, Vol. XXIII, part 3, page 166.

Serial Number	Title of Publication	Author	Reference
41.	Germination of sugar cane pollen in artificial culture media.	N. L. Dutt and G. Ganapathi Ayyar	Agri. Jour. India, Vol. XXIII, part 3, page 190. 1928.
42.	Factors influencing the growth and sugar contents of sugar cane.	K. Krishnamurti Rao	Agri. Jour. India, Vol. XXIV, part 2, page 91. 1929.
43.	Longevity of sugar cane pollen.	N. L. Dutt	Agri. Jour. India, Vol. XXIII, part 6, page 482. 1928.
44.	Studies of sugar cane roots at different stages of growth.	T. S. Venkatraman and R. Thomas	Mem. Dept. Agri. India, Bot. Ser. Vol. XVI, No. 5. 1929.
45.	What portion of the sugar cane to plant.	T. S. Venkatraman	Agri. Jour. India, Vol. XXIV, part 1, page 60. 1929.
46.	Certain features of sugar cane root systems and the importance of their study.	T. S. Venkatraman	Proceedings of the 1928 Convention of the Sugar Tech. Association (India)
47.	An apparatus for testing rind hardness in sugar canes.	Dr. A. N. Puri and T. S. Venkatraman	Proceedings of the 1928 Convention of the Sugar Tech. Association (India).
48.	Supply of sugar cane varieties from the Imperial Sugar cane Station, Coimbatore.	T. S. Venkatraman	Agri. Jour. India, Vol. XXIII, part 5, page 404. 1928.
49.	Problems before the sugar cane breeder (With special reference to Indian conditions).	T. S. Venkatraman	Proceedings of the 3rd Convention of the Int. Soc. Sugar Cane Technologists, Java. 1929.

APPENDIX

Current Investigations at Coimbatore

(Season 1930)

During this part of the year, i. e., from August to December, the investigations bear mainly on the problem of breeding.

Thin Cane Area

Arrowing—(I) The influence of the time of planting on arrowing—it is found possible to have a difference of two to three weeks in flowering by planting in different seasons. (II) The influence of nitrogenous and phosphatic fertilizers on

arrowing—phosphatic fertilizers hasten the time of flowering by a week or so. (III) Smoking to induce early arrowing—results inconclusive. (IV) Wrapping up and spraying of tassels in the field to prevent emergence of anthers—results negative.

Fertility, Receptivity of the Stigma—It is believed that the failure of the canes of the various Indian groups may be, in part, due to the dryness and consequent non-receptivity of the stigma. (I) Spraying the stigmas just before pollination with a 1 per cent solution of commercial sugar—last year's results with the thick canes rather encouraging—no data yet obtained from the thin canes.

Root Studies—Experiments to develop a method by which the functional regions of a root system can be studied. No success as yet.

Crosses made—Besides a few experimental crosses the following general crosses were made:

(I)—Co. 290 x Co. 281.
(II)—Co. 290 x Co. 214.
(III)—P. O. J. 2725 x Cholam (Andropogon Sorghum).

A very large number of Co. 214 selfed tassels were collected from the field. They germinated excellently. Also general crosses were gathered from the field, i. e., tassels were gathered from the field without reference to the pollinating parent. The cross between P. O. J. 2725 and Cholam is of more than passing interest. This is probably the first instance where a plant of another genus has been crossed with *Saccharum officinarum*. I am told that they were attempting this cross for the last two or three years and only this year it has succeeded. The appearance and other studies, I have been told, indicate definitely that the seedlings are real offsprings of P. O. J. 2725 and Cholam.

Thick Cane Area

Arrowing—(I) To control flowering by shortening the period of daylight or by prolonging it by artificial light—results nil so far. (II) To induce arrowing by enclosing the top in an atmosphere of ethylene chlorhydrin—results nil.

Fertility, Stigma Receptivity, etc.—(I) Inducing fertility by spraying the stigmas with 1 per cent sugar solution—last year's results encouraging—no data as yet on this year's work. It is claimed that by treating in this manner, seedlings were obtained from P. O. J. 2714.

Anthers, Pollen—(I) Controlling dehiscence of anthers or rendering pollen infertile by spraying with varying strengths of sodium chloride. (II) Experiments to preserve pollen in a viable condition over a long period.

Seeds, Seed Setting, etc.—(I) The effect of artificial rooting on seed setting (II) The effect on germination of soaking seed in orthophosphoric acid, or other chemicals. (III) The effect on germination of drying seeds in an oven of 40° C. or over—no data on any of these obtained as yet.

Selfing—The effect of keeping tassels in a closed room, on seed setting.

Crosses made—The following crosses were made:

(1) Vellai x Co. 213
(2) " x P. O. J. 2878
(3) " x B 3412
(4) " x Co. 285
(5) " x 247 B
(6) " x P. O. J. 2696
(7) " x D 74
(8) " x Co. 281
(9) " x M 58231
(10) " x Q 813
(11) " x Co. 290
(12) " x Fiji B
(13) " x Co. 243
(14) P. O. J. 2725 x Co. 243
(15) " x B 3412
(16) " x Co. 214
(17) " x Fiji B
(18) " x Co. 281
(19) " x Co. 290
(20) " x Q 813
(21) B 6308 x Q 813
(22) " x Co. 281
(23) " x Co. 290
(24) " x D 74
(25) " x M 58231
(26) " x Fiji B
(27) Maur. 1237 x Co. 285
(28) " x B 3412
(29) " x Co. 243
(30) " x D 74
(31) " x M 58231
(32) " x Q 813
(33) " x Co. 281
(34) " x Co. 290
(35) " x Fiji B
(36) Co. 290 x 247 B
(37) " x Q 813
(38) " x S. W. 111
(39) " x Fiji B
(40) " x P 360
(41) Co. 213 x D 74
(42) " x B 3412
(43) " x P. O. J. 2878
(44) " x S. W. 111
(45) " x Q 813
(46) P. 384 (Co. 213 Self) x P. O. J. 2727.
(47) P. 384 x P. O. J. 2878
(48) " x E. K. 28
(49) " x D 74
(50) " x S. W. 111
(51) " x B 3412
(52) H 109 x Q 813
(53) Maur. 33 x Fiji B
(54) P. O. J. 2364 x Co. 281
(55) P. O. J. 2878 x B 3412
(56) " x Co. 285
(57) " x Co. 243
(58) S. W. 111 x M 58231
(59) Fiji B x B 3412
(60) Chittan x Co. 243
(61) " x 247 B
(62) B. H. 10 (12) x Co. 290
(63) Kassoer x D 131
(64) " x B 3412
(65) " x Co. 290
(66) " x Fiji B
(67) " x B. H. (10) 12

Besides a few experimental crosses.

China as a Potential Market*

(Abridged from "Commerce Reports")

China has long been regarded as a potential sugar consumer, but the purchasing power of the Chinaman is small and if the consumption of sugar is to increase the price must be kept low. In 1924 the *per capita* consumption of sugar was put at only 4 lbs., but at present is believed to range between 4½ and 5 lbs. This low figure is due to the poor standard of living of the masses. The poorer classes enjoy sweets, but consume sugar and candy sparingly. Agricultural products having a high sugar content, such as raw sugar cane and baked sweet potatoes, are sold on the street by the hawkers, as is hard candy of a decidedly poor quality. The Chinese use little coffee and still drink their tea unsweetened. Sugar candy or rock sugar is regarded as a luxury, selling as a sweetmeat in the interior. Soft white sugar is the most popular, being eaten with chopsticks.

Both cane and beet sugar are produced in China, the former having been cultivated for centuries, and records show that fair amounts of Chinese sugar were imported into New York during the 18th century. It has always been regarded as a luxury and has often constituted the tribute to the ruler from those provinces that cultivated it. Cane sugar is now produced principally in the provinces of Szechwan, Kwantung and Fukien. The estimated production in these provinces during 1927 was between 210.000 and 235,000 long tons. Beet sugar is produced principally in Manchuria and the provinces of Shansi and Hopei.

According to latest reports, there are ten refineries and six sugar factories in China, Hong Kong and Manchuria. The great bulk of the sugar made is produced in small mills employing crude processes. Three kinds of sugar are made, green (dark brown), brown (light brown) and white. The imported sugar is divided into five varieties—brown, white, refined, cube or loaf, and sugar or rock candy, Java, Hong Kong, Japan and Formosa being the principal suppliers. Brown sugar is used largely by the refineries for mixing with native sugar, but is also extensively employed by confectioners and bakers, and by native doctors. White sugar is classified according to color, the best grade being used by households of the better classes. Refined includes all sugar treated with bonechar, or of a color equalling or superior to No. 26 D. S. Sugar candy shows a wide latitude, including all kinds of sugar in large crystals, rock candy being the most popular.

Shanghai and Hankow are the most important sugar markets. Dealers from several Provinces have buying offices established there, as well as in Hong Kong, Tientsin and Swatow. The trade is believed to be shifting from British to Dutch control, as sugar from Java and Sumatra is selling in the local markets at prices less than the British product.

Only a few of the largest firms have an established marketing system. They

* Taken from *The International Sugar Journal*, February, 1931, Vol. XXXIII, pp. 61-63.

have Chinese dealers throughout the interior who are bonded to the importing firm through the deposit of title deeds, bank guaranties, or other collateral. Sugar is shipped to the dealers on open account, and at the end of each month or other stated period the dealers remit to the firm the receipts, less selling commission from the sales. The ordinary importing firms do not have agents. They obtain orders for future delivery from the local sugar merchants and in turn place these orders abroad. Upon arrival of the sugar in the port, the firm notifies the local merchants, who, according to the terms stipulated in the buying contract, take delivery in 10 days, 1 or 2 months. The practice of taking delivery in 10 days is becoming quite general. The volume of "spot" business is insignificant. After taking delivery of shipment from the importing firm, the local merchant effects shipment to his customers throughout the region.

Brown sugar manufactured in China and Japan is packed in mat bags, reinforced with rattan or split bamboo strips of 133 lbs. (1 picul) to 200 lbs. (1½ piculs) net weight. Brown sugar from Java and the Philippine Islands is packed in jute bags of 220 lbs. net weight. White and refined sugar manufactured in China and Japan and white sugar from Java is packed the same as brown sugar. Refined sugar from Java and white sugar from Cuba is packed in double jute bags of 220 lbs. (100 kilos) net weight. Refined sugar from Hong Kong is packed in single jute bags of 133 lbs. or in cotton bags of 100 lbs. Cube and loaf sugar is packed in cartons of 1 lb. and 5 lbs. and shipped in cases of 50 lbs. net. Sugar candy from Java is packed in jute bags of 333 to 360 lbs. net weight, while that from the United States and Europe is in jute bags of 100 lbs. net, and that from Japan in wooden cases of 6-7 lbs. Upon arrival in China, the sugar candy is repacked in cartons and tins, ranging in size from an ounce or so to 5 or 10 lbs. net. This article is in high favor as a gift, and for this reason the cartons and tins are usually attractive.

Imports of sugar into China during the last five years, for which statistics are available, according to statistics taken from "Foreign Trade of China." issued by the Inspector-General of Customs at Shanghai, were as follows:

Year	Long Tons
1928	818,091
1927	599,715
1926	696,600
1925	687,275
1924	530,360

Competition in the Chinese sugar market is very keen. If one is to compete successfully, it will have to be on a price basis, meeting quality requirements on a parity with competing sugars now established in the local trade. To be introduced successfully, it may even be necessary to sell slightly below current prices, until a foothold is obtained.

[J. N. P. W.]

Root Studies at Coimbatore

By U. K. Das

Systematic studies of sugar cane roots have begun only in recent times. Such studies give invaluable information not only to the scientist who wants to know all about the plant he is dealing with but also to the actual grower who can profit by them to improve his cultural practices. Lee and his associates in Hawaii and Venkatraman and Thomas at Coimbatore have done considerable amount of pioneer work. The work in Hawaii was confined to the thick canes only. The Coimbatore work, on the other hand, embraced different species of wild Saccharums, as well as different groups of the cultivated form of sugar cane. The work in Hawaii was more quantitative seeking to get exact information as to the amount of roots that are obtained at different depths of the soil, etc. The Coimbatore work, by the very nature of circumstances, lent itself more to interesting qualitative and comparative studies.

Summary of Coimbatore Work

Attention was first drawn to the interesting differences among the varieties, when, in the earlier years of the Coimbatore Station, a large number of stools were dissected to obtain information on tillering, etc. Real work appears to have started somewhere in 1919 and 1920. The first paper (1) by the joint authors appeared in 1922. It was shown in that paper that the different varieties had characteristically different root systems, that in the same variety the nature and the quantity of roots varied according to the type of soil, that the type of soil even modified the cell tissues of the roots and that a characteristic root system could be imparted to seedlings by suitable selection of parents.

In the second paper (2) the authors set forth the results of their detailed studies on the influence of the different types of soils on root systems, on the functional regions of the sugar cane roots, on the activity of root hairs, etc.

In the third paper (3) the authors have given detailed information on the development, nature and function of primary roots and adventitious roots ("Sett" roots and "Shoot" roots respectively—as the authors have called them). This paper also describes "certain interesting adaptations in sugar cane roots, such as aerotropic curvatures and arrangements for ensuring an efficient rooting."

Technique

In studying root systems of plants growing actively in the soil, a reliable technique is of the utmost importance. In fact it is the absence of an efficient technique that impedes progress along this line. In Coimbatore, the following methods have been tried:

(1) Dig pits on both sides of the cane stool at a certain distance from the

center—remove the soil slowly and carefully so as not to disturb the course of the roots or break them.

(2) Dig pits on both sides, insert iron rods across, wash the soil through these rods leaving the roots exposed and held between the rods.

(3) Lay strips of wire netting in the soil in the bottom of the row, plant cane as usual. At the desired time, remove the soil by washing. This method is open to great criticism, as the soil thus artificially prepared may not give the exact conditions found normally in the field.

(4) Make a column by placing several earthen rings one upon another. The rings have sides of one foot. Put wire netting in between the rings, fill the column with soil, taking care to simulate the texture in the field. Plant cane as usual, on the top of the column. At any time, rings can be removed to study the development of roots. This method, for obvious reason, is rather unreliable.

(5) Water culture—the cultures being made in earthen pots which are placed in the field itself. This method is useful only to a limited extent.

(6) In studying "Sett" versus "Shoot" roots, the authors have used the following method: Plant a piece of cane several internodes long, vertically in the soil. Allow only the topmost bud to sprout. Direct the shoot roots into the soil held in a paper tube. The tube is made of thick paper and paraffined outside and inside. It is claimed that by placing a particular type of soil in the tube, the development of roots in that soil can easily be studied.

The method generally employed at present is the first one. Pits are dug 3 to 4 feet away from the center of the row. Trained women laborers then get into the pit and with the help of a thin iron rod, pick the soil carefully so as to leave the roots intact in their place. Sometimes the roots are held in place by inserting a thin bamboo stick in the ground. Should a root break, in spite of all the care, the broken portions are at once joined together by a ball of clay. After the dissection has been completed, the roots can be seen in the pit more or less in their natural position; as the accompanying illustrations will show. Dissection of one side of a stool of cane may take one to two days. One man and two women are employed for the purpose. The pits may measure 5 feet by 3 feet or more and as many feet in depth.

After the system, thus exposed, has been studied, the soil is put back.

This method gives an excellent idea of the root system at any particular time; but it is doubtful if the same stool can be dug again to give reliable information as to the progress of the roots since the last excavation. This method is extremely laborious and would be quite expensive in Hawaii.

Attempts are being made to devise a method by which the actively growing roots can be studied *in situ*. No method used so far can give an exact idea as to the feeding ground of the root tips and root hairs.

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Fig. 1. Exposed root system of a wild cane (Saccb. Spont.).

Fig. 2. Women laborers in the pit carefully removing soil from around the roots.

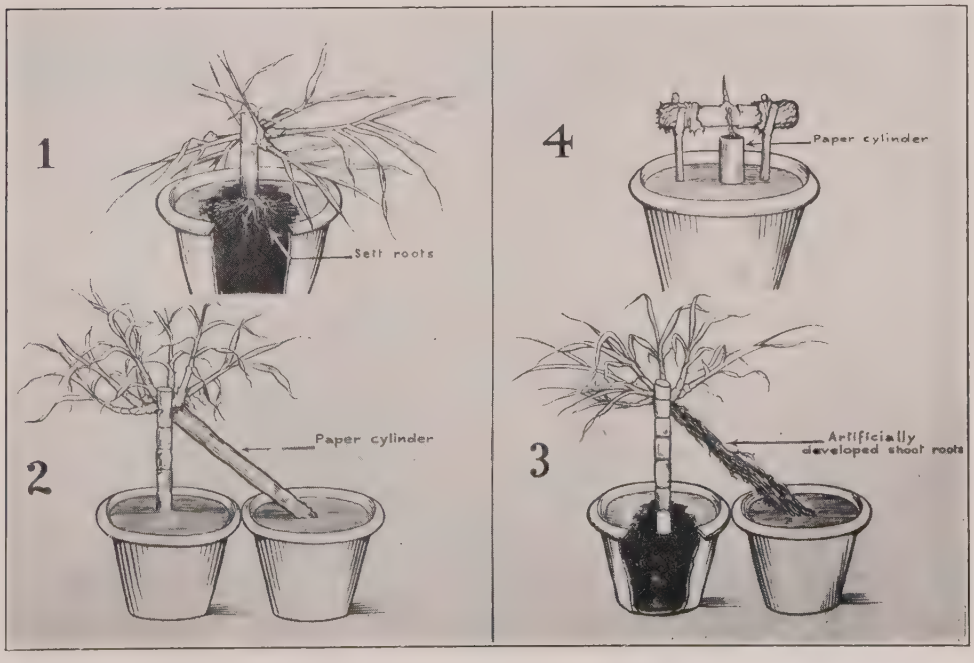

Fig. 3. Method of studying root development—the adventitious roots are being led into tubs containing different kinds of soil (No. 3). By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

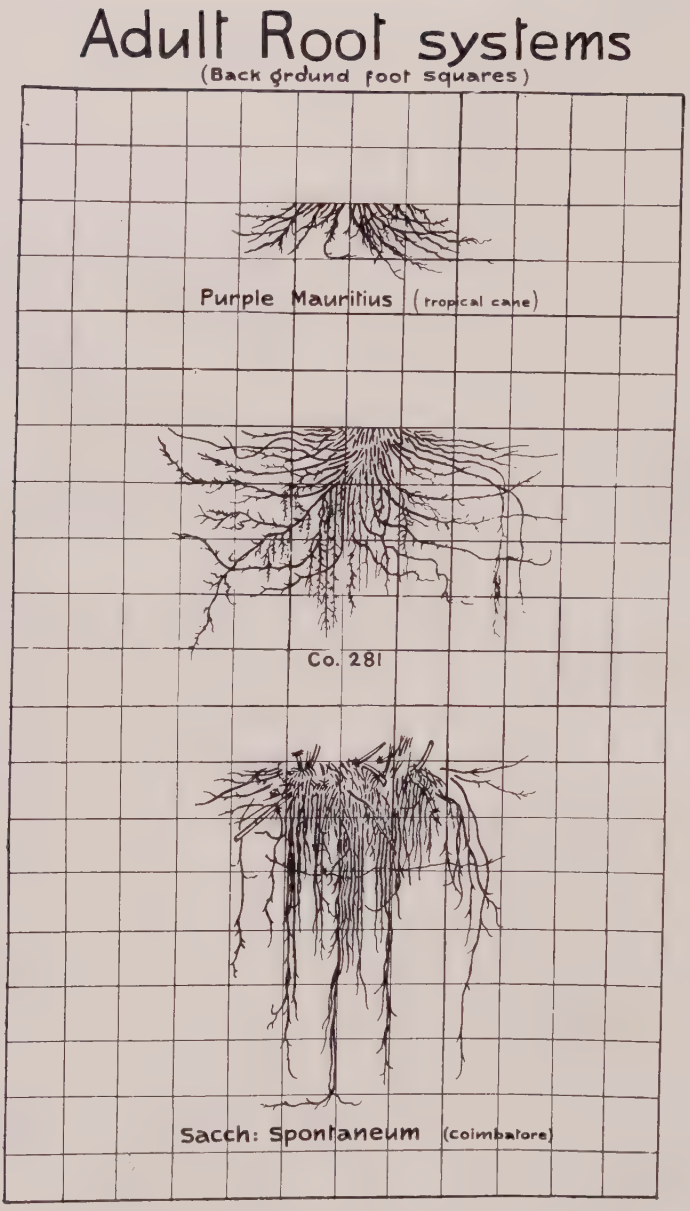

Fig. 4. Note the differences in the mode of root growth. By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

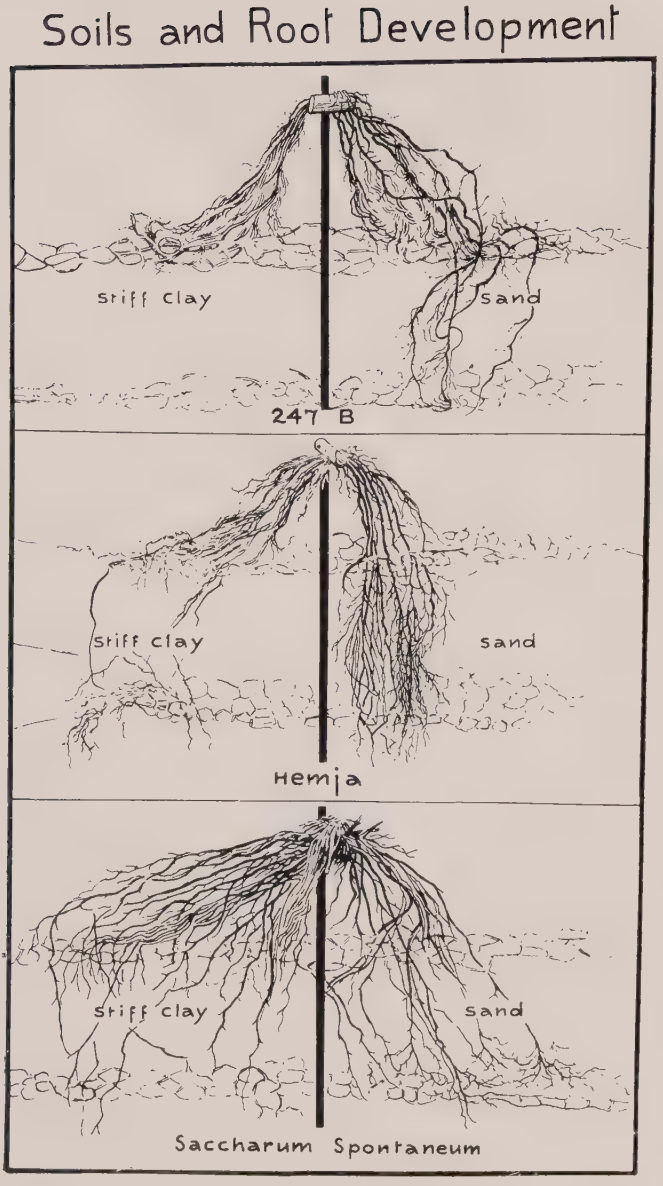

Fig. 5. 247 B and Hemja show much better root growth in a sandy (loam) soil but the wild cane Saccb. Spont. is equally at home in both the stiff clay and the sandy loam. By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

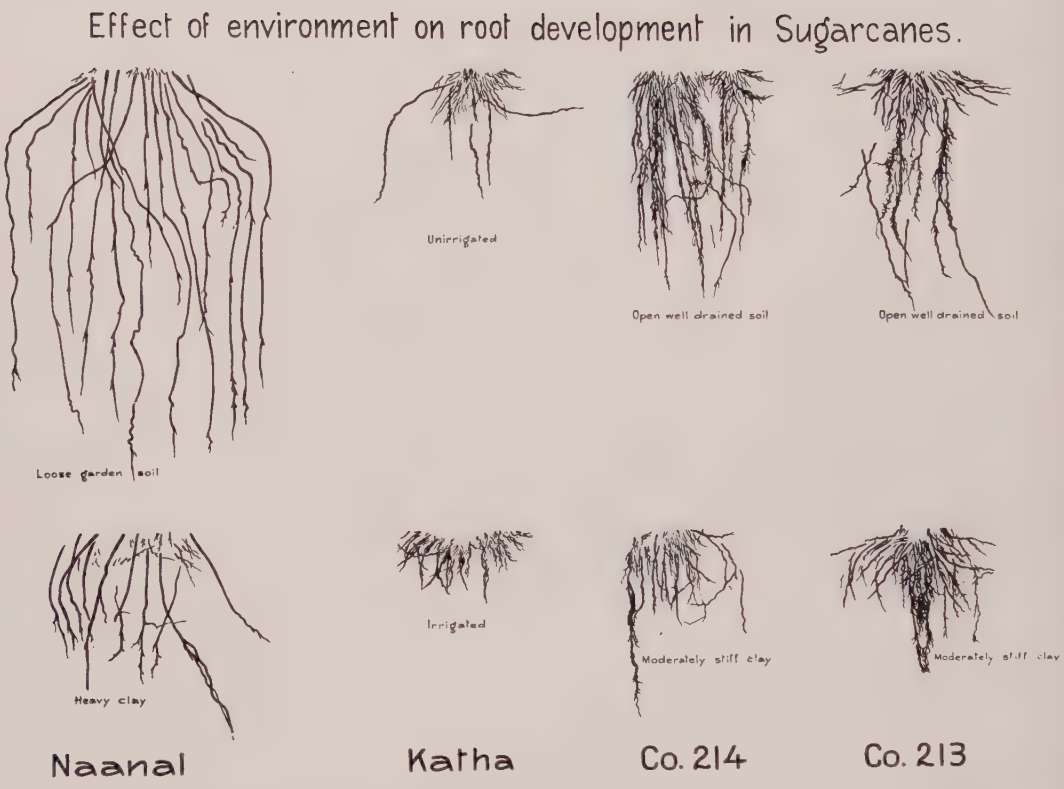

Fig. 6. This picture brings out not only the varietal differences but also the differences in root growth due to varying environments. By courtesy of the Govt. Sugar Cane Expert, Coimbatore, India.

Diseases, Malformations and Blemishes of Sugar Cane in Hawaii

By J. P. Martin

New or heretofore unrecorded diseases are observed from time to time accompanying the propagation of new cane varieties, the modification of agricultural practices, as well as variations that may occur in environmental or climatic conditions. It is possible that these diseases have been present for a long period of time in an inconspicuous or latent form and their symptoms are only recognized with the culturing of new varieties that prove highly susceptible, or, with a change of conditions, favorable to their development. It is well established that some varieties are highly resistant to specific diseases and yet may act as carriers without manifesting any definite symptoms of a diseased condition. The existence of certain diseases is more easily detected when susceptible canes are cultivated in contact with the highly resistant ones. For this reason observations made on mixed groups of seedlings of different parentage offer the best chances for detecting new troubles or abnormalities.

A disease is manifested by a deviation from the normal function or structure and is usually recognized by structural changes, depressed growth, development of abnormalities, the presence of various types of chlorosis, the occurrence of definite spots, stripes, blotches, or markings, or the interruption of physiological activities of the plant. A disease may affect a portion of or the entire plant and may cause a premature death of that portion of the plant affected.

Diseases affecting sugar cane plants may be divided into three groups, namely (1) non-parasitic, due to poor physical qualities or conditions of the soil, nutritional disturbances, environmental conditions, etc.; (2) parasitic, due to specific organisms such as fungi or bacteria living at the expense of the cane plant, and (3) virus diseases, due to ultra microscopic entities of unknown nature which are so small that they will pass through the pores of a Berkefeld or Chamberland filter and still be capable of producing a disease. Insects play an important role in this group of diseases since they frequently act as carriers of the virus and incidentally inoculate healthy plants during their search for food.

Articles pertaining to the major cane diseases have appeared in the *Hawaiian Planters' Record* and occasional mention has been made of the minor troubles. The object of this article is to present, as nearly as possible, a complete list of all known diseases, malformations and blemishes affecting sugar cane in Hawaii. It will be necessary to extend the present list as new diseases are observed.

In presenting this outline the cane plant, for convenience of discussion, has been divided into its component parts, namely: leaves, leaf sheaths, stalks, roots and tassels; another grouping has also been used which includes the entire plant. Certain diseases, for example, are recognized by the presence of definite symptoms appearing on particular parts of the plant; thus the maladies affecting or occurring

on the leaves have been listed separately. A further division has been made according to whether the symptoms of the diseases affecting the leaves assume the form of spots, blotches, streaks, stripes, a wilting or rolling of the leaves, a rotting of the spindle, a malformation of the cane top, irregular bands, various types of chlorosis or burns. The diseases affecting the other parts of the plant are handled in a similar manner.

Following each disease the name of the causal agent appears. Insect injury resembles a diseased condition under certain circumstances and for this reason is included in the following outline:

I. AFFECTING THE LEAVES	CAUSAL AGENT
A. Spots or Blotches on Leaves	
Eye spot	*Helminthosporium sacchari* Butler (fungus)
Brown stripe	*Helminthosporium stenospilum* Drechsler (fungus)
Pokkah boeng	*Fusarium moniliforme* Sheldon (fungus)
Ring spot	*Leptosphaeria sacchari* van Breda (fungus)
Sooty mold	*Capnodium* sp. (fungus)
Red discoloration of midrib (Red rot disease)	*Colletotrichum falcatum* Went (fungus)
Leaf scald	*Bacterium albilineans* Ashby (bacterium)
Mosaic	A filterable virus
Banded chlorosis	Low temperatures
Purple discoloration	High elevations, low temperatures, lightning injury, and inherited characteristics
Pale whitish blotches near or adjoining leaf sheath	Inherited characteristic
Midrib blotch	Undetermined
Mechanical abrasion	Mechanical friction or wind whipping
Lightning injury	Lightning
Leaf stipple	Undetermined
Leaf freckle	Undetermined
Reddish blotches due to leaf mites	*Tetranychus exsiccator* Zehntner (mite)
Large reddish irregular blotches due to cane aphis feeding	*Aphis sacchari* Zehntner (insect)
Thrip injury	*Thrips saccharoni* Moulton (insect)
B. Streaks or Stripes on Leaves	
Eye spot	*Helminthosporium sacchari* Butler (fungus)
Brown stripe	*Helminthosporium stenospilum* Drechsler (fungus)
Red stripe	*Phytomonas rubrilineans* Lee et al (bacterium)
Leaf scald	*Bacterium albilineans* Ashby (bacterium)
Mosaic	A filterable virus
Chlorotic streak	Undetermined
Pahala blight	Manganese or iron deficiency
Leaf variegation	Inherited characteristic
Mechanical abrasion	Mechanical friction or wind whipping
Iron deficiency	As a result of soluble calcium in the soil

C. Wilting or Rolling of Leaves	
Red rot	*Colletotrichum falcatum* Went (fungus)
Pineapple disease	*Thielaviopsis paradoxa* (de Seynes) v. Hohn (fungus)
Leaf scald	*Bacterium albilineans* Ashby (bacterium)
Following growth failure	(See Part VI)
Wind burn	Excessive transpiration
"Knife cut"	Undetermined
Water deficiency	Insufficient soil moisture or excessive transpiration
Iron injury	Excessive ferric iron in soil solution
Aluminum injury	Excessive soluble aluminum in soil solution
Excessive fertilization	Toxicity of applied nutrients
D. Rotting of Spindle (Top Rot)	
Eye spot	*Helminthosporium sacchari* Butler (fungus)
Pokkah boeng	*Fusarium moniliforme* Sheldon (fungus)
Red rot	*Colletotrichum falcatum* Went (fungus)
Iliau	*Gnomonia iliau* Lyon (fungus)
Growth failure	(See Part VI)
Red stripe	*Phytomonas rubrilineans* Lee et al (bacterium)
Leaf scald	*Bacterium albilineans* Ashby (bacterium)
Borer injury	*Rhabdocnemis obscura* Boisduval (insect)
Banded (sectional) chlorosis	Low temperatures
Pahala blight	Deficiency of available manganese or iron
Lightning injury	Lightning
Iron injury	Excess of soluble ferric iron in soil solution
Aluminum injury	Excess of soluble aluminum in soil solution
Fertilizer burns	Fertilizers applied on foliage
Aborted tassels	Undetermined
E. Malformation of Cane Top	
Pokkah boeng	*Fusarium moniliforme* Sheldon (fungus)
Bunch top	Undetermined
Twisted or tangle top	Mechanical entanglement of leaves
F. Irregular Bands on Leaves	
Pokkah boeng	*Fusarium moniliforme* Sheldon (fungus)
Banded or sectional chlorosis	Low temperatures
Pale blotches on leaf near or adjoining leaf sheath	Inherited characteristic
G. Chlorosis	
1. Entire Leaf	
Leaf scald	*Bacterium albilineans* Ashby (bacterium)
Coral chlorosis (limestone)	Excessive soluble calcium
Ratoon chlorosis	Undetermined
2. Leaves Affected in Part	
a. Streaks	
Leaf scald	*Bacterium albilineans* Ashby (bacterium)
Mosaic	A filterable virus
Pahala blight	Manganese or iron deficiency in soil
Leaf variegation	Inherited characteristic
Chlorotic streak	Undetermined
b. Bands or blotches	
Pokkah boeng	*Fusarium moniliforme* Sheldon (fungus)
Banded chlorosis	Low temperatures
Pale blotches on leaf blade near or adjoining leaf sheath	Inherited characteristic

H. Leaf Burns	
Leaf scald	*Bacterium albilineans* Ashby (bacterium)
Wind burn (formerly called leaf burn)	Excessive transpiration
Fertilizer burn	Fertilizers applied on foliage
Fire injury	Fires
Salt spray injury	Wind-blown sea water
Injury from weed sprays	Chemicals
Lightning injury	Lightning
Oil injuries	Oil and grease from implements, etc.
Midrib blotch (whitish)	Undetermined
II. AFFECTING THE LEAF SHEATHS	
Leaf scald	*Bacterium albilineans* Ashby (bacterium)
Iliau (binding)	*Gnomonia iliau* Lyon (fungus)
Red rot (selerotial disease)	*Sclerotium rolfsii* Kruger (fungus)
Phyllosticta spot	*Phyllosticta hawaiiensis* Caum (fungus)
Stem mites	*Tarsonemus spinipes* Hirst (mite)
III. AFFECTING THE STALKS	
A. External Symptoms	
1. Spots or Streaks	
Eye spot	*Helminthosporium sacchari* Butler (fungus)
Red stripe	*Phytomonas rubrilineans* Lee at al (bacterium)
Mosaic	A filterable virus
Stem mites	*Tetranychus exsiccator* Zehntner (mite)
Mealy bug injury	*Trionymus sacchari* (Cockerell) (insect)
Sunburn	Direct sun rays
Leaf hopper egg punctures	*Perkinsiella saccharicida* Kirk. (insect)
2. External Growths	
Stem galls	Undetermined
3. Breaking of Rind	
Pokkah boeng	*Fusarium moniliforme* Sheldon (fungus)
Rind disease	*Melanconium sacchari* Mass. (fungus)
"Knife cut"	Undetermined
Borer injury	*Rhabdocnemis obscura* Boisduval (insect)
Rat injury	*Rattus* spp. (rodent)
B. Malformation of Stalk	
Zigzag joints	Undetermined
Bifurcated stalks	Undetermined
Diagonal nodes	Undetermined
Budless nodes	Undetermined
Constriction of stalk	(1) *Gnomonia iliau* Lyon (fungus) (2) *Helminthosporium sacchari* Butler (fungus)
C. Internal Symptoms	
1. Discoloration of Bundles	
Pokkah boeng	*Fusarium moniliforme* Sheldon (fungus)
Leaf scald	*Bacterium albilineans* Ashby (bacterium)
Red stripe	*Phytomonas rubrilineans* Lee et al (bacterium)
Chlorotic streak	Undetermined
Root rot, advanced stage	*Pythium aphanidermatum* (Edson) Fitz. (fungus)
2. Discoloration, General	
Red: decay	Injuries; mechanical, fungal, followed by secondary decay organisms
Red: red-rot type	*Colletotrichum falcatum* Went (fungus)
Black: Pineapple disease type	*Thielaviopsis paradoxa* (de Seynes) v. Hohn (fungus)

IV. AFFECTING THE ROOTS

A. Fungous Rots

Pythium type	*Pythium aphanidermatum* (Edson) Fitz. (fungus)
Marasmius type (rare)	*Marasmius sacchari* Wakker (fungus)

B. Nematode Injuries

Red lesions	*Tylenchus similis* Cobb (nematode)

C. Other Animal Injuries

Root trimming by Anomala grubs	*Anomala orientalis* (Waterhouse) (insect)
Pitting caused by springtails (most abundant)	*Isotomodes* sp. (insect)
Pitting caused by centipedes	(1) *Mecistocephalus maxillaris* (Gervais) (centipede) (2) Undetermined species
Pitting caused by snails	*Geostilbia baldwini* (Ancey) (snail)
Pitting caused by symphylids	(1) *Scolopendrella* sp. (garden centipede) (2) *Scutigerella* sp. (garden centipede)

D. Malformations

1. Swellings and Distortions

Nematode galls	*Heterodera radicicola* (Greef) (nematode)
Distorted roots (and mechanical galls)	Soil structure
Excessive branching	Following injuries to growing point, chemical, biological or mechanical stimuli

E. Non-parasitic Blemishes

Reddened roots	Exposure to light and air

V. AFFECTING THE TASSEL

A. Aborted Tassels

Tassel rot	Undetermined
Bunch top	Undetermined

VI. AFFECTING THE ENTIRE CANE PLANT (GROWTH FAILURE)

A. Parasitic Root Rots

Pythium growth failure	*Pythium aphanidermatum* (Edson) Fitz. (fungus)
Weak parasites-Marasmius type	*Marasmius sacchari* Wakker (fungus)

B. Nematodes, Affecting Roots

Galls	*Heterodera radicicola* (Greef) (nematode)
Lesions or punctures	*Tylenchus similis* Cobb (nematode)

C. Nutritional Disturbances

Salt injury	Excess of sodium or magnesium salts in soil
Aluminum and iron toxicity	Excess of iron and aluminum
Manganese toxicity	Excess of manganese
Unfavorable base ratio	Unbalanced calcium and magnesium ratio
Nitrogen deficiency	Inadequate supply of available nitrogen
Potash deficiency	Inadequate supply of available potash
Phosphate deficiency	Inadequate supply of available phosphate
Manganese deficiency	Inadequate supply of available manganese
Iron deficiency	Excess of calcium or manganese in soil
Water deficiency	Inadequate soil moisture
Deficiency of one or more of the less essential elements	Such as boron, copper, titanium, zinc, arsenic, etc.
Excess of any one chemical element	Excess of nutrients, ferric iron, etc.
Excess of coral in surface soil or marl in subsoil (See chlorosis under I-G)	Abnormal soil conditions

The above outline has been prepared in collaboration with plantation personnel and Station staff members with the idea of using it in a "Handbook of Sugar Cane Diseases in Hawaii," that is now being prepared. In this handbook an account will be given embracing such points as the history, description, transmission and control measures of each disease listed.

Weather and the Quality of Juice at Ewa

By U. K. Das

In our previous study (1) of the relation of weather conditions to the sugar yields of the Ewa Plantation Company, no attempt was made to segregate the influences of weather on the quality of cane apart from the tonnage or quantity of cane. In the present paper we propose to discuss specifically the relation of weather conditions to the quality of cane.

It is generally agreed that weather has a great deal to do with the quality of our cane juices. The question arises: What element or elements of the weather is it that affect the juices? Is it temperature, sunshine, rainfall or is it anything else? Again is it only the weather during the harvesting season that is of importance or the weather of any preceding period during the lifetime of the crop? We hear of such statements as cool weather improving the quality of juice or excessive rainfall depressing it. But when we try to apply these observations to actual data, we are often disappointed. These generalizations do not suffice to explain the differences in the quality of juice from one year to another. Our disappointment arises no doubt from the fact that we know so little of the physiological processes of a ripening cane. Before we can answer such questions as: Why such good juices in 1925 and why such poor ones in 1927? We need to know more and more precisely of the manner in which sucrose is accumulated in cane. The problem is, indeed, difficult; whereas we know of ways of measuring the effect of such factors as temperature, moisture, etc., on the outward processes of cane growth, we have as yet no satisfactory method of measuring the changes that take place inside the cane plant. It is this inherent difficulty that has led most of the investigators to approach this problem of juice quality in an indirect manner. That is, instead of directly measuring the effect of weather factors such as temperature, bright sunshine, etc., on juices, they have delved into the past history and tried to correlate the quality of juices with the weather conditions prevailing during the growing period of the crop. Significant relations have been established which have proved to be reasonable and sound. Our method of approach is essentially the same.

Previous Work

Browne and Blouin (2) found that in Louisiana cool weather preceding the harvesting season improved the sucrose content of cane. The more recent study of McDonald (3) confirmed the findings of Browne and Blouin. But this study also showed that super-normal mean temperature in the preceding summer and also at the beginning of the harvesting season was necessary for high sugar content. McDonald also found that excessive rainfall in the months preceding harvest was detrimental while sunshine during the same period was helpful in obtaining good juices. Koenig (4) in Mauritius found that both cool and dry weather

before harvest improved juice quality. Tengwall and Van der Zyl (5) in Java showed that the percentage of sugar from year to year was favorably influenced by excessive rainfall in the latter months of the planting year and unfavorably by excessive rainfall in the opening months of the cropping year. In Hawaii, the work of Das (6) showed that at the Pepeekeo Sugar Company, good juices were associated with dry weather in the grinding season, but with super-normal rainfall in the growing months of the previous year. The same worker also found that moderately high mean temperature during and preceding the grinding season was not only not harmful but it had a favorable influence on the sucrose content of cane. The present study is a little different from the others just cited in that it deals with the juices of an efficiently irrigated plantation, where the variations in seasonal rainfall are not likely to cause serious disturbances.

Materials and Methods

The subject of our investigation is the quality of juice (1904-1917) from a selected group of Lahaina fields. This group of fields comprises an area of about 1000 acres each year and it was shown in our previous study (1) that we have reasons to believe the averages from these fields represent the average yield of the plantation. In a latter part of this paper, the deductions from the study of 1904-1917 have been utilized to explain the differences in the quality of juice of some recent years.

The statistical methods are also the same as in our previous study. Only in the present case we have gone a step further in that we have tried to determine the influence of temperature or sunshine on sugar content by eliminating the possible influence of an interdependence of the two factors. This is known as the method of partial correlation. For the theory and development of these methods, we would refer the reader to some standard book on statistics.

Meaning of the Correlation Coefficients

A coefficient is positive (+) or negative (—) depending on whether an increase in one variable is associated with an increase or decrease of the other variable. Thus if increasing temperature increases sucrose content then we say that temperature has a positive correlation with sucrose, if on the other hand increase in temperature brings about a decrease in sucrose content, we say that the correlation between the two is negative. According to Fisher (7), where the number of items is fifteen, as in the present case, a correlation of $\pm$ .56 or more is of definite significance. Some writers prefer to call the periods showing such significant correlations as periods of "critical importance." Thus, if winter temperature and sugar content has a significant correlation of $\pm$ .60, we would conclude that the sugar content is influenced more by the temperature in winter than at any other period having a correlation of less than .56. Also, whereas a crop will be able to get over the good or poor conditions at other periods, it will be permanently benefited or injured by the conditions obtaining in the "critical periods."

The Average Weather at Ewa

We have records of the following weather conditions at Ewa Mill:

(1) Daily and average monthly maximum temperature.

(2) Daily and average monthly minimum temperature.

(3) Daily and average monthly mean temperature.

(4) Daily and total monthly precipitation.

(5) Number of clear and cloudy days in a month. (A clear day has over 75 per cent of the sky clear and a cloudy day over 75 per cent of the sky cloudy.)

The complete records are given in an appendix to this report. The normal for the years 1903-1917 are shown in Fig. 1. We would draw attention to the following points: (a) at Ewa. January, February and March constitute the winter months, December being warmer than March; (b) the extreme dryness of the spring, summer and fall months and insignificant amount of rain in the rainy months; (c) the unexpectedly low number of clear days in the fall months.

Quality of Juice—Definitions

By juice, in this report, we mean specifically crusher juice though we intend this term to include total juice extracted. We have two aspects of the quality in mind—namely, (a) the polarization of the crusher juice, (b) the purity of the crusher juice.* In general high polarization means high purity, but not always.

Polarization of Crusher Juice

Table I and Fig. 2 show the polarization of crusher juice of the crops of 1904 to 1917 for the selected group of Lahaina fields, as well as the average polarization of all the fields of the plantation. It will be noted that the averages of the selected fields show the same nature of fluctuation as the averages of all the fields. This fact makes us surer of the reliability of our data from the selected Lahaina fields.

Table II gives the deviations of the individual years from the mean of the odd or even years. The odd and even years are grouped separately as an additional precaution against introducing the error of field variability, for under the cultural conditions of 1904 to 1917 the same fields were harvested in the alternate years.

Temperature and Polarization

Two distinct processes are involved in the life of the cane plant. One is of assimilation, by which the plant takes in carbondioxide from the air to build up sucrose and other carbohydrates and proteins. This process goes on only at daytime under the influence of light. The other is the counter process of respiration which breaks up the assimilated material to supply the energy for many chemical changes that take place inside the plant. At night, in the dark, only the process of respiration goes on. Both of these processes are markedly influenced by tem-

* Purity per cent $= \frac{\text{Pol}}{\text{Brix}} \times 100$; Thus, Purity is a measure of solids other than sucrose in the cane juice.

perature. Obviously, for an understanding of the accumulation of sucrose in cane, we would be mainly interested in the average day temperature and the average night temperature. As such records are not available at Ewa, we have taken the average maximum temperature as an index of day temperature and the average minimum temperature as an index of night temperature.

Table III gives the coefficients of partial correlation between maximum or minimum temperature and polarization. Fig. 3 is a graphic presentation of the same data. In the years 1904-1917, the average time of starting the crop was the months of July and August and the crop was in the field for nearly two years. The coefficients have, therefore, been obtained for every month during the growth period of the crop.

TABLE I

Polarization and Purity of Crusher Juice

Crop Year	Polarization of Juice Per Cent		Purity of Crusher Juice Per Cent	
	Average of All Fields	Average of Selected Fields	Average of All Fields	Average of Selected Fields
1904	15.5	15.7	86.6	86.3
1905	16.9	16.9	87.1	87.1
1906	17.3	17.6	87.5	88.4
1907	16.5	16.7	88.1	88.5
1908	16.9	16.6	90.3	90.6
1909	17.8	18.0	91.7	92.0
1910	16 8	17.7	88.6	89 6
1911	17.7	18.2	89.4	90.4
1912	17.0	17.9	87.6	89.4
1913	16.7	17.5	87.0	88.6
1914	16.3	17.5	85.8	88.1
1915	16.5	17.5	86.0	89.0
1916	15.3	16.6	84.1	87.2
1917	15.7	17.1	85.8	88.8
1924	15.77		86 13	
1925	15.99		86.95	
1926	15.73		85.68	
1927	15 42		85.57	
1928	15.80		86.77	
1929	16.13		86.86	

TABLE II

Deviations of the Percentage of Polarization in Crusher Juice from the Mean of Odd and Even Years Respectively

	Pol Per Cent	Deviation from the Mean		Pol Per Cent	Deviation from the Mean
1905	16.9	— .5	1904	15.7	—1.4
1907	16.7	— .7	1906	17.6	+ .5
1909	18.0	+ .6	1908	16.6	— .5
1911	18.2	+ .8	1910	17.7	+ .6
1913	17 5	+ .1	1912	17.9	+ .8
1915	17.5	+ .1	1914	17 5	+ .4
1917	17.1	— .3	1916	16.6	— .5
Mean	17.4		Mean	17.1	

TABLE III

Correlation Coefficients Between Polarization and Purity of Crusher Juice and Weather Factors

	Partial Correlation Polarization and			Total Correlation Polarization and			Total Correlation Purity and			
	Mean Max. t°	Mean Min. t°	No. of Clear Days	No. of Cloudy Days	No. of Part Cloudy Days	Rainfall	Max. Temp.	Min. Temp.	No. of Clear Days	Rainfall
2 Years Ago:										
July	+.07	—.59	—.30					—.35		
August	+.41	—.71	+.39				—.08	—.15	+.26	
September	+.46	—.67	+.12				+.20	—.18	+.29	
October	+.47	—.60	+.34				+.20	—.08	—.15	
November	+.26	—.06	+.76				+.39	—.21	+.18	
December	+.16	+.04	+.36				+.30	+.10	+.16	
1 Year Ago:										
January	+.30	—.39	—.05				+.15	+.06	—.25	
February	+.40	—.25	—.14				+.58	+.14	+.32	
March	+.15	+.23	+.31				+.26	+.52	+.23	
April	—.05	—.17	+.20				+.05	—.49	+.22	
May	—.28	+.14	+.35				+.15	+.01	+.18	
June	—.22	+.06	—.12				—.06	—.04	+.03	
July	—.11	—.40	+.37	—.30			—.09	—.37	—.18	
August	+.17	—.42	+.32	—.42			—.10	—.24	+.33	
September	—.16	—.23	—.20	+.07			—.02	—.30	+.26	
October	+.42	—.77	+.45	+.11			+.14	—.69	+.14	
November	+.13	+.15	+.63	—.32		—.47	+.43	—.36	+.71	
December	—.32	—.44	+.51	—.32		—.27	+.15	—.30	+.54	—.14
Crop Year:										
January	—.44	—.25	+.46	—.43	+.19	—.32	+.18	+.00	+.29	—.24
February	+.25	—.23	—.14	+.02	+.20	—.03	+.35	+.22	—.07	—.29
March	+.43	—.53	+.28	—.20	+.04	—.50	+.21	+.23	+.23	+.02
April	+.61	+.10	—.33	+.05	+.15	+.07	+.34	—.10	—.05	
May	+.34	+.38	+.48	—.45	+.28	—.04	+.44	+.15	+.34	
June	+.15	+.41	—.36	—.10	+.51					
Significance	.58	.58	.63	.60	.60	.55	.55	.55	.60	.55

Discussion

In Fig. 4, free-hand curves are presented which show in a simple manner the trend of correlation coefficients. These curves also indicate the relative seasonal needs of maximum and minimum temperature for high polarization in cane. Incidentally, these help us to understand the way in which sucrose is accumulated in a crop.

From the same figure we see that maximum temperature has a positive correlation with sugar content in the fall and winter months of the first season, negative correlation in the second season summer and in the months immediately before harvest, and positive relation again in the harvesting months. This means that to get high polarization we should have maximum temperature super-normal in the first season, sub-normal in the summer and winter months of the second season and super-normal again in the harvesting season. Now maximum temperature is an index of day temperature and it is during the daytime that the vital process of photosynthesis and assimilation goes on. High maximum temperature means favorable conditions of assimilation and growth during the daytime. Therefore, it is easy to see why high maximum temperature should be essential in the first season for it is at this time that cane plants are young and growing at a fast rate, sending out new shoots and building that spacious store-house of cells where sucrose is to be accumulated later on.

In the second season summer, the crop is already well advanced; if the summers are too hot at this time vegetative growth may continue at a rapid rate and very little sucrose accumulate in the cane. Also it is probable that in an arid place like Ewa, excessive heat tends to increase the concentration of soil solution and, thereby, cause greater absorption of non-sugars by the cane plant. The work of Row (8) in India and Thieme (9) in Java show that a high percentage of non-sugars in the cane is associated with low sucrose content and low purity of juice. The need of cool weather in the late fall and early winter months is in agreement with the popular saying that "cool weather sweetens the cane." Cool weather decreases vegetative activity and gives the plant a chance to start accumulating sugar.

Again there is need for high maximum or day temperature in the harvesting season. Whether the effect of high temperature at this period is of any physiological significance we do not know. Yet it is conceivable that the changes in the concentration and acidity of the juice as the cane plant approaches the harvesting stage, together with high maximum temperature may accelerate the activity of certain enzymes that are helpful to sucrose accumulation. Also, high maximum temperature at this stage may slightly increase the concentration of juice by bringing about a reduction in the percentage of moisture in the cane. Verret and others (10) found a reduction of 2 to 3 per cent in moisture in mature cane from which irrigation water had been withheld for 60 to 90 days. In Table III we see that there is only one period of "critical significance," the month of April of the cropping year, which would indicate that warm days are very necessary in this period.

The coefficients of minimum temperature are almost all negative, which means

that for high polarization in cane minimum temperature should always be below normal. In other words, as minimum temperature is an index of night temperature, for high polarization in cane the nights should be always cool. Undoubtedly that is why places where the fall in temperature is great at night, have been observed to produce sweet canes. Why are low night temperatures so essential for high sugar content? The beneficial effect of low night temperature is explained this way. At daytime the plant gains by assimilation and it loses part of it at night by respiration, so that the total gain of matter to the plant may be represented by an equation. Total gain of matter = Total matter assimilated — matter lost by respiration. It is obvious, therefore, that assimilated material being the same the greater the loss by respiraion the less is the gain to the plant. High night temperatures increase the respiratory activity of the plant thus inducing great losses of assimilated matter. The following figures from Lundegardh are quoted by Blackman (11) to show the effect of increasing temperature on the hourly loss, by respiration at night, from one hectare of potato field:

RESPIRATION LOSS PER HOUR PER HECTARE

Temperature	0°	5°	10°	15°	20°	25°
Losses (Kilogramme)	0.45	1.0	1.5	2.0	3.0	4.5

A second table from the same source (11) gives the assimilation and respiration of an oat field at two night temperatures.

ASSIMILATION AND RESPIRATION PER HECTARE

Assimilation	Respiration	Gain
300 K. grams	175 Kg. (20° C.)	125 Kg. (330-175)
300 K. grams	132 Kg. (10° C.)	168 Kg. (300-132)

Thus, a difference in temperature of 10° C. at night made a difference of over 30 per cent in the total weight of matter gained by the oat field. In sugar cane, most of the matter gained is stored in the form of sucrose and it is clear from the foregoing that low night temperature will increase the amount of sugar in the plant, conditions of assimilation being the same.

That sugar cane is not the only plant to show such temperature relationship is proved by the work of Gregory (12) on barley. Gregory found that the net assimilation rate had significant positive correlation with day temperature and negative correlation with night temperature.

Obviously the ideal condition would be high day temperature and other favorable growing conditions by day and low night temperature by night. That such is actually the case with sugar cane for a considerable period of its growing time is shown by the simplified curves of Fig. 4. As regards minimum temperature, two periods appear to be significant or of critical importance. These are the first few months after starting in the first season of the crop and the fall months of the second season, especially the month of October preceding harvest.

That cool nights are necessary in the months just before harvest will be generally agreed to, for that is the time when the crop as a whole is slowing down growth and entering into the ripening stage. It is in this period that the crop should be extremely susceptible to favorable ripening weather.

The great need of cool nights and, as we have previously noted, of warm days in the first season point again to the conclusion that in the life of a sugar cane crop the first few months are of the utmost importance.

For optimum conditions the days should be warm and the nights cool in the first season. This may mean that the cane plant benefits by a big range in temperatures in the first season. Harrington (13) and Morinaga (14) have shown that alternating high and low temperatures hasten the germination of seeds and bulbs. If the buds of sugar cane react as favorably towards a great range of temperature, then we are likely to have earlier suckering, which would mean a greater number of mature stalks at harvest and hence a higher sucrose content.

Also, for the best development of certain higher plants a great range of temperature is essential, whether the sugar cane is one of them we do not know.

Number of Clear Days and Polarization

It is generally known that some plants grow well in shade and that others require plenty of sunlight for maximum development. The tropics being the natural habitat of the sugar cane, it would seem reasonable to assume that the cane plant also will thrive best when there is an abundance of sunshine and clear days. That such is actually the case at Ewa is borne out by our studies.

In the absence of data on the actual hours of sunshine, the number of clear days may be taken as a good index of the condition of light.

Table III and Fig. 5 show that the coefficients of correlation between clear days and polarization are almost always positive. This means that we are likely to have high polarization at Ewa when the amount of sunshine is more than normal throughout the growth of the crop. Therefore, there is more truth than poetry in the saying that "sugar is crystallized sunshine."

There are two periods of "critical importance"—the fall months of the first season, specifically the month of November and the fall months just prior to harvest, particularly again the same month of November. We believe that the "critical importance" of an abundance of clear days in the first season is due to the fact that this abundance promotes early suckering. Verret and McLennan (15) in Hawaii, Brenchley (16) in England have shown definitely that the plants receiving more sunlight have always a greater number of early and vigorous suckers. The investigations of Rodrigues (17) prove that early suckering is closely associated with high sugar content of a cane crop. As we have said once before, early suckering means a greater number of mature stalks at harvest and consequently the average sucrose content for the crop is higher.

There is not much need indicated for an extra amount of sunlight in the second season spring and summer, possibly because Ewa's normal of twenty-five clear days per month in those seasons is enough anyway.

The "critical importance" of sunshine in the second season fall months is easily understandable. The normal for Ewa at this season is rather lower than we should expect (Fig. 1) and it is at this period that the crop is entering into the ripening stage and therefore needs all the sunshine it can get so that it can elaborate a greater amount of sugars.

We also worked out a few coefficients of correlation between cloudy days and sugar content and part cloudy days and sugar content. It is significant that the coefficients of cloudy days are generally negative and those of part cloudy days slightly positive. This entirely confirms what we have said about a large number of clear days being essential for high sugar content.

Temperature and Purity

The average purities for the selected group of Lahaina fields are to be found in Table IV and Fig. 6.

The coefficients of total correlation between maximum temperature and purity, and between minimum temperature and purity are given in Table III and Fig. 7.

The coefficients indicate that purity is influenced by maximum temperature in the different months in about the same way as polarization is. For high purity there is need for super-normal maximum or day temperature in the first season summer and super-normal temperature again in the fall and winter months preceding and during harvest. Only one month, the month of February in the first season, is significant.

Great interest attaches to the steady decline in the values of the coefficients from the first season February on until the value becomes definitely negative in the summer months and continues to be so until September of the second season. The harmful effects of high day temperature are to be explained by the fact that high temperature causes greater absorption of non-sugars. It is also of interest that need is indicated for super-normal day temperature in the fall months before harvest.

TABLE IV

Deviations of the Percentage of Purity of Crusher Juice from the Mean of Odd and Even Years Respectively

	Purity Per Cent	Deviation from the Mean		Purity Per Cent	Deviation from the Mean
1904.....	86.3	—2.2	1905.....	87.1	—2.1
1906.....	88.4	— .1	1907.....	88.5	— .7
1908.....	90.6	+ 2.1	1909.....	92.0	+ 2.8
1910.....	89.6	+ 1.1	1911.....	90.4	+ 1.2
1912.....	89.4	+ .9	1913.....	88.6	— .6
1914.....	88.1	— .4	1915.....	89.0	— .2
1916.....	87.2	—1.3	1917.....	88.8	— .4
Mean	88.5		Mean	89.2	

TABLE V

Number of Clear Days This Year and the Average Purity of Crusher Juice in the Crop Harvested Next Year (i. e. Number of Clear Days in 1907 and the Purity of Juice for the 1908 Crop)

Crop of	No. of Clear Days Previous Year	Purity of Juice Per Cent All Fields	Crop of	No. of Clear Days Previous Year	Purity of Juice Per Cent All Fields
1908.....	209	90.3	1919.....	119	86.4
1909.....	225	91.7	1920.....	151	83.1
1910.....	198	88.6	1921.....	116	83.9
1911.....	189	89.4	1922.....	115	86.6
1912.....	202	87.6	1923.....	73	84.6
1913.....	236	87.0	1924.....	117	86.13
1914.....	191	85.8	1925.....	170	86.95
1915.....	184	86.0	1926.....	154	85.68
1916.....	166	84.1	1927.....	129	85.57
1917.....	157	85.8	1928.....	81	86.77
1918.....	148	85.2	1929.....	98	86.59

The coefficients of minimum temperature again indicate the need for cool nights for a considerable period of the growing time of a crop. The periods of "critical importance" are, of course, the fall months prior to harvest, especially the month of October. It is of interest that the first season months are not as significant as regards high purity as they were in the case of high polarization. The explantation may be that we cannot begin to think of purity of juice until sucrose has begun to be stored in any appreciable amount in the cane plant, which would, normally, be in the second season.

Number of Clear Days and Purity

The correlation coefficients (Table III, Fig. 8) indicate the need of brighter days throughout the entire life of the crop. As polarization and purity are closely correlated, this would almost follow from what we found to be the relation of clear days and polarization.

Here again it is not the first season that is of much importance to high purity, but the fall months of the second season, particularly the months of November and December preceding harvest.

Fig. 9 shows the close relation between purity of crusher juice at Ewa and the number of clear days in November before harvest. Table V and Fig. 10 show that the fluctuations in the purity of juice from year to year bear a definite relationship to the number of clear days in the year preceding harvest, which will be the year 1905 for the crop of 1906. That such would be the case would follow from the curve of "theoretical optimum" Fig. 8 (B).

Rainfall and the Quality of Juice

We have not thus far considered rainfall not because we do not consider it of great significance, in fact in some localities it is the most important factor in cane ripening, but, because at Ewa the cane is sought to be ripened artificially by with-

holding irrigation water and that rainfall in the grinding season does not amount to enough to be of possible significance. To verify our point, we have worked out the coefficients of correlation beween polarization and rainfall, Table III. The coefficients are all negative, and not one is significant. In other words, supernormal rainfall immediately before and also during the harvesting season, is not favorable to obtaining high polarization, but this is a factor of minor importance under the conditions of Ewa.

Quality of Juice in Some Recent Years

The investigations presented so far in this paper considered the quality of juice of a selected group of Lahaina fields from 1904-1917. If our deductions are sound in principle then, we should be able to apply them to the quality of juice of variety H 109 and explain in a general way why such good juices in 1925 and such poor ones in 1927. Cultural practices have been the same for both of these years, but the crusher juice in 1925 had a polarization of 15.99 per cent and purity of 86.95 per cent, and that of 1927 a polarization of 15.41 per cent and purity of 85.57 per cent.

In Fig. 11, we have compared the conditions of minimum or night temperature during the growing time of the crop of 1925 and 1927. The "theoretical optimum" as deduced from our study is also presented. It will be seen clearly from these curves that 1925 had a much better weather for high quality cane than 1927.

Curves in Fig. 12 show the conditions of light for the crops of 1925 and 1927. Comparing the conditions in the two years, with the "theoretical optimum" curve, there is again no question as to why 1925 was a year of better juices than 1927. Our previous deductions are thus proved to be entirely sound.

Practical Applications

At this point some of us might ask: What is the good of all this? We will agree that we need cool nights and bright days for high sucrose, but we cannot make them to order. So, we might just as well lie back and let nature take its course. But surely we cannot be so helpless. There is a saying: "If the mountain does not come to Mahomet, Mahomet must go to the mountain." If we cannot change our weather we can surely imitate the way it works; we may try to create the same conditions of growth as good weather does. In the following pages we explain our view point.

"Critical Importance" of the First Season of Growth

We have seen that the effects of both day and night temperatures are very marked in the first season. As a result of this and our previous studies (1), (6), we have come to look upon the first season as the most important season in the life of our sugar cane crop. Clarke's (18) observations in India also point to the same conclusion. It is at this time that the crop is growing at a fast rate, new suckers are being formed, a stand is being made; it is at this time that the foundations of a good crop are being laid. While a crop reflects all the benefits of a

favorable growing condition at this time, it "never forgets and hardly ever forgives the bad treatment it has received."

Our cultural practices should be such as to give the very best care, water, fertilizer, etc., to the young crop. The growing practice of bringing water to the ratoons and starting them soon after harvest is, therefore, a move in the right direction.

Promote Early Suckering

We have said that the effect of clear days in the first season is to promote early suckering. We have cited the work of Rodrigues (17) to prove that early suckering means high sucrose content. Here, we shall explain in detail why we consider early suckering to be so important.

The curve (B) in Fig. 13 has been prepared from some growth measurement data at the Paauhau Sugar Plantation Company.* Here is shown the volumetric rate of growth at various ages of cane growing under actual field conditions. It will be noted that cane less than twelve months old is still growing at a fast rate.

Curve (A) in Fig. 13 has been prepared from the growth Experiment "E" at Waipio. The averages are for cane planted at different seasons of the year. We see from this curve that the Quality Ratio or theoretical tons cane per ton sugar improves with age up to twenty-four months. We also note that cane less than fifteen to twelve months old has a tremendously poor juice.

From considerations of curves A and B in Fig. 13 it will be obvious that if we have a large number of young suckers, growing at a fast rate and having a poor juice, included in our crop, the average quality ratio will be very poor. In Table VI data are produced from two experiments at the Paauhau Sugar Plantation Company. In one case, Field 14B was harvested at 21 months and had 19 per cent of the stalks below 15 months age; in the other case, Field 4A harvested at 24 months only 4 per cent were less than 15 months old at harvest. Under such circumstances, other conditions being similar, we are likely to get better juices from a field whose average "stalk-age" is greater than another whose stalk-age is lower. We have used this term stalk-age to denote the average age of all the stalks in a crop, and this term by itself affords an excellent index by which to judge the ripening of a field. In Table VI we see that in the Paauhau field harvested at 24 months, the stalk-age was only 21 months, in the case of one harvested at 21 months the stalk-age was only 18. Can we not gather data from the plantation fields that will indicate the age of the average stalk and do it as a form of agricultural control?

It follows from the foregoing that in order to get good juices, we should not have any stalk in our crop that is less than 15 to 12 months old. In other words, we must promote early suckering and once having obtained the suckers we should try to prevent new shoot growth in the second season. Stubbs (19) was one of the pioneers with this point in view.

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* We are indebted to the manager of the Paauhau Sugar Plantation Company for allowing us permission through R. J. Borden, to make use of the data.

TABLE VI

Paauhau Sugar Plantation Company

Growth Experiment—Number and Proportion of Stalks of Various Ages Included in the Harvest of the Experimental Fields

Field 14½-B—Irrigated, Ratoons of D 1135. Harvested at 21 Months. May, 1927.
Field 4-A—Irrigated, Ratoons of D 1135. Harvested at 24 Months. February, 1927.

Age at Harvest	Field 14½-B No. of Stalks Harvested	Per Cent of Total Number Harvested	Field 4-A No. of Stalks Harvested	Per Cent of Total Number Harvested
24			86	46
23			..	
22			1	0.7
21	93	48	..	
20	..		18	11
19	..		..	
18	..		49	26
17	20	12	..	
16	..		24	12
15	37	21	..	
14	..		5	1
13	35	12	..	
12	..		10	3
11	23	7	..	
Total stalks harvested	208	100	193	100
Average age of stalks	17.1 months		20.1 months	

In this connection experiments are in order on two subjects:

(1) What is the stooling habit of H 109 or any other standard cane? If A is the mother stalk and B and C the daughter and grand-daughter stalks respectively, then, what would be the formula for an average stool of H 109 in the field? Is it A + YB or it is A + YB + ZC? We should also know at what age or at what stage of development of the mother plant the secondaries or tertiaries develop. We know that some canes, such as the wild Saccharum, send out new shoots continuously, others stool early and still others stool late. A knowledge of the stooling habit of our standard canes will enable us to determine what practices to follow to encourage early and discourage late suckering.

(2) We should know what effect second season fertilization has on second season suckering, and on the quality of juice. Personally, we consider that our fertilizer practice in its relationship to increased vegetative growth and suckering needs careful scrutiny. Of recent years the application of commercial fertilizers per acre, especially of nitrogen, has increased considerably, while at the same time the average age of our crop has been decreasing. To our mind, this fact alone may account for the gradual decline in the quality of our juices. From physiological considerations, as we give more plant food to our crops, as we increase vegetative growth, we need to allow more time so that active vegetative growth may cease and ripening begin.

Other points that should be considered in this connection are:

(A) Planting material or seeds for the plant field: Should we treat our seeds

so that we may stimulate germination and early growth? Will it not be found profitable to have seed nurseries, the same as they have in Java?

(B) Spacing: If more space in between the rows means more sunlight and if sunlight promotes suckering, should we reconsider our present practice of spacing, keeping in mind the considerations set forth in this paper and also the cultural conditions of today?

Need for Greater Knowledge of the Physiology of Sugar Cane

This study has impressed on us in a very forcible manner the need for greater light on the obscure physiological processes that go on inside the cane plant. For a proper understanding of the influence of environment on sugar cane, for a more intelligent appreciation of its needs, for larger yields, we must have a better grasp of the fundamental principles governing the life processes of the sugar cane.

Summary

The following are presented as a summary of this paper:

A. At Ewa, cane juice of high average quality for the crop will result when weather conditions pertaining thereto are as follows:

(1) The days warmer than normal in the first season, cooler than normal in the second season summer and the late fall and winter months, and warmer again in the spring months of the cropping year.

(2) The nights always cooler than normal, especially so in the first season and in the months preceding harvest.

(3) A large proportion of clear days throughout the crop, especially so in the fall months of the first season and in the months preceding harvest.

(4) Rainfall during the harvesting season below normal, but this factor is not as important as the others just enumerated.

B. References are made to problems demanding study and suggestions are offered as to the ways in which the deductions from this weather study may be made use of in the field.

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APPENDICES

EWA PLANTATION COMPANY

APPENDIX A

Monthly Mean Maximum t°

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1901	79.4	77.5	81.4	85.9	85.7	86.7	86.6	87.7	86.5	85.6	82.6	81.2
1902	82.9	78.4	78.2	80.7	81.4	84.0	85.4	86.1	86.0	84.8	81.0	79.0
1903	78.0	70.6	78.0	81.0	83.6	85.0	86.0	86.7	85.8	83.0	81.5	80.7
1904	79.2	75.7	76.3	78.4	82.0	82.9	84.5	85.0	85.2	81.6	78.1	77.5
1905	73.5	75.4	76.1	77.7	79.8	81.5	82.4	82.4	81.9	80.1	79.0	75.6
1906	74.4	76.1	75.7	82.7	84.2	85.8	86.5	86.9	87.1	86.2	83.6	80.3
1907	80.1	80.0	78.6	80.9	84.4	85.9	86.1	86.2	87.0	85.0	82.4	81.5
1908	79.3	80.1	79.6	80.9	83.6	84.3	85.1	86.0	85.4	84.1	82.5	79.2
1909	78.2	78.4	77.0	80.5	83.3	85.4	85.4	86.1	86.3	84.8	83.5	80.1
1910	77.6	78.8	81.0	80.5	82.6	84.0	85.7	86.1	85.6	84.1	81.9	79.3
1911	76.8	77.9	79.5	82.2	83.7	84.6	85.8	87.7	85.7	84.1	82.2	79.7
1912	79.1	79.3	78.6	82.0	84.1	85.1	86.6	87.7	87.4	86.0	82.5	81.1
1913	80.6	79.3	81.5	82.8	83.5	85.2	87.5	88.2	87.7	86.8	83.1	81.2
1914	77.9	80.6	79.5	82.0	83.5	86.1	86.5	88.2	86.5	86.2	82.3	78.8
1915	77.9	77.4	80.2	81.4	84.9	87.0	87.4	88.5	87.9	85.4	81.4	79.3
1916	77.7	80.4	80.1	82.1	82.4	83.4	84.6	84.3	84.4	83.5	81.3	78.8
1917	78.2	78.3	78.9	80.9	83.4	84.7	86.1	86.5	86.7	85.3	82.6	80.6
Avg. 1903-1917	77.9	78.2	78.7	81.1	83.3	84.7	85.7	86.4	86.0	84.4	81.9	79.6
1918	80.6	78.9	78.6	78.2	82.4	84.1	86.0	86.3	86.4	86.4	83.2	79.6
1919	78.6	80.0	80.0	82.1	83.7	86.0	86.6	87.5	86.6	85.3	83.5	81.2

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1920	79.3	81.2	81.1	82.0	84.6	85.5	86.1	87.2	87.5	86.1	82 8	80.2
1921	78.3	80.8	81.2	82.4	83.9	86.9	86.9	86.7	86.4	84.3	82.2	80.3
1922	79.3	78.2	80.4	82.6	83.1	85.6	87.1	86.7	86.5	85.0	82.8	82.3
1923	78.9	79.6	80.3	82.9	85.2	86.8	87.6	88.5	87.9	87.2	83.6	80.3
1924	79.7	81.3	81.3	81.4	84.5	85.7	86.8	86.9	87.3	85.6	83.0	81.7
1925	81.5	84.0	81.8	81.2	83.4	84.6	86.0	86.5	86.4	86.1	83.2	81.5
1926	80.8	81.0	82.1	80.8	84.8	85.7	87.5	87.5	87.4	85.6	83.0	81.9
1927	80.0	81.0	80.9	82.6	84.1	86.0	83.4	86.8	87.2	85.2	81.9	80.3
1928	78.8	80.0	81.5	83.3	83.6	85.8	86.4	86.9	86.8	85.3	82.3	80.3
1929	78.8	79.6	81.2	83.7	84.2	86.2	87.7	88.0	87.8	85.9	82.0	79.1
1930	78.7	81.5	79.9	81.2	84.5	86.3	87.2	87.4	87.1	86.3	84.0	....

APPENDIX B

Monthly Mean Minimum t°

1901	67.0	65.2	68.1	68.9	68.5	69.1	69.4	70.6	68.7	68.6	67.1	64.8
1902	62.6	62.5	67.2	64.2	66.7	69.5	70.4	72.0	69.8	67.5	67.0	63.0
1903	61.0	60.0	58.0	65.0	66.4	67.0	71.0	70.9	69.7	68.0	65.3	64.2
1904	64.2	62.7	63.7	65.6	64.2	66.7	67.6	68.7	68.2	67.7	64.1	64.2
1905	55.9	57.3	58.6	62.6	65.7	66.3	68.8	70.4	69.2	67.0	65.8	61.7
1906	61.0	59.9	59.0	64.7	64.6	69.2	69.4	70.5	69.2	68.7	65.3	64.8
1907	64.5	62.2	63.0	61.6	65.1	67.8	68.5	71.2	70.1	67.6	66.2	63.9
1908	61.1	61.8	63.9	63.7	66.0	66.2	67.0	67.9	66.9	65.7	62.5	63.1
1909	60.1	61.3	63.6	62.9	65.4	68.6	69.5	68.2	67.6	67.1	64.0	63.5
1910	62.2	60.1	63.1	64.0	64.6	67.3	67.3	67.9	67.4	66.5	65.8	61.9
1911	62.6	61.6	62.4	65.2	66.2	68.2	69.9	70.7	69.9	66.1	65.1	64.2
1912	61.4	62.0	60.7	64.6	65.6	66.9	68.5	79.5	69.2	69.0	65.4	66.1
1913	62.4	59.9	62.7	65.3	65.6	67.5	68.3	....	69.0	68.1	66.9	61.9
1914	60.6	59.8	61.3	63.6	65.7	68.0	76.1	71.5	71.5	68.1	65.9	61.7
1915	60.7	61.1	61.3	62.8	66.0	68.5	69.8	71.1	69.7	68.7	67.1	65.0
1916	62.6	62.3	64.2	65.1	66.7	67.4	68.0	67.3	67.7	67.4	66.5	63.4
1917	60.4	60.2	63.4	63.7	64.4	66.5	67.2	68.0	67.3	65.9	65.2	63.2
Avg. 1903-1917	61.4	60.8	61.9	64.0	65.5	67.5	68.7	69.6	68.8	67.4	65.4	63.5
1918	61.5	61.9	61.3	63.8	63.8	66.6	69.5	69.2	67.5	68.2	64.1	63.7
1919	59.2	61.3	60.8	63.3	64.5	66.6	68.4	69.2	66.7	66.1	63.4	61.0
1920	59.7	59.6	61.7	62.7	63.5	63.9	68.4	68.6	68.0	66.6	63.4	62.9
1921	63.1	59.9	61.1	63.1	62.8	67.4	67.3	67.5	67.3	64.5	63.2	63.0
1922	61.1	60.9	61.2	63.2	63.1	64.1	65.5	66.3	66.0	64.7	62.4	59.3
1923	62.5	56.8	60.4	62.2	63.3	63.9	66.6	66.5	66.3	64.4	62.8	61.5
1924	55.2	58.7	58.7	60.7	62.5	62.7	65.1	65.0	64.2	64.3	61.5	59.5
1925	62.1	59.3	59.5	61.7	62.2	63.9	64.9	65.5	62.6	62.4	62.4	62.3
1926	61.0	61.2	61.3	61.0	66.3	67.1	68.0	68.2	68.4	66.9	63.6	64.2
1927	62.2	60.9	64.3	64.1	66.0	67.3	66.0	67.9	67.3	65.8	65.9	63.4
1928	61.7	58.7	61.0	63.6	64.5	65.2	67.6	68.0	66.6	65.6	64.0	62.9
1929	59.2	60.8	62.1	63.9	64.2	66.3	66.5	68.0	68.1	67.5	65.0	61.8
1930	59.3	60.4	62.0	62.1	64.6	66.2	68.5	70.2	69.3	66.3	63.7	....

APPENDIX C

No. of Clear Days

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1906.....								22	18	13	9	10
1907.....	6	20	10	19	20	25	20	20	18	16	14	21
1908.....	17	13	11	18	19	22	22	21	20	20	21	21
1909.....	15	9	13	11	22	20	20	26	18	17	..	11
1910.....	11	12	22	15	15	14	22	23	6	16	17	..
1911.....	9	13	14	15	19	25	21	22	14	11	18	21
1912.....	19	14	9	22	26	20	25	22	22	22	19	16
1913.....	19	15	11	20	20	21	18	10	11	13	11	22
1914.....	7	8	5	15	20	26	31	20	11	21	7	13
1915.....	28	13	9	3	14	18	21	19	7	17	4	13
1916.....	1	8	15	15	15	22	24	17	14	11	11	4
1917.....	7	10	10	18	8	21	23	18	16	9	3	5
Avg. 1903-1917.	13	12	12	16	18	21	22	20	15	16	12	14
1918.....	2	0	0	2	16	14	21	13	16	12	12	11
1919.....	12	9	8	12	20	10	13	26	7	11	11	12
1920.....	9	12	2	12	17	15	13	9	19	2	4	2
1921.....	0	9	14	16	5	23	14	10	11	8	3	2
1922.....	0	2	7	5	9	5	13	6	5	3	6	12
1923.....	2	1	5	12	20	19	26	17	4	6	3	2
1924.....	17	13	12	3	19	14	18	26	24	7	8	8
1925.....	16	11	7	7	24	21	19	22	9	9	4	5
1926.....	13	7	15	10	19	5	18	12	10	4	12	4
1927.....	5	6	2	5	3	18	6	8	19	7	2	0
1928.....	13	8	6	11	8	8	7	19	12	0	0	6
1929.....	18	6	11	1	9	18	15	11	9	7	2	13
1930.....	..	6	..	12	31	21	20	8	8	..	..	..

Fig. 1

Ewa Plantation Co.

Average Monthly Weather Conditions at Ewa Mill.

(Ave. 1903-1917)

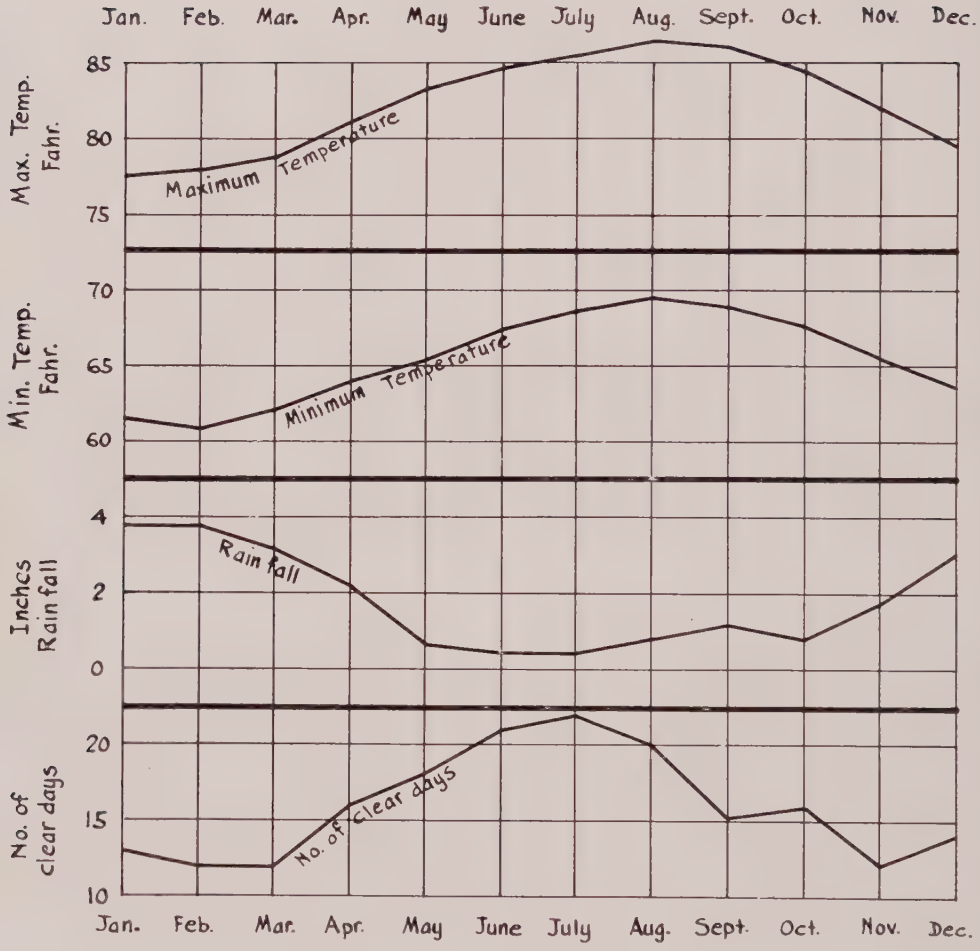


Fig. 2

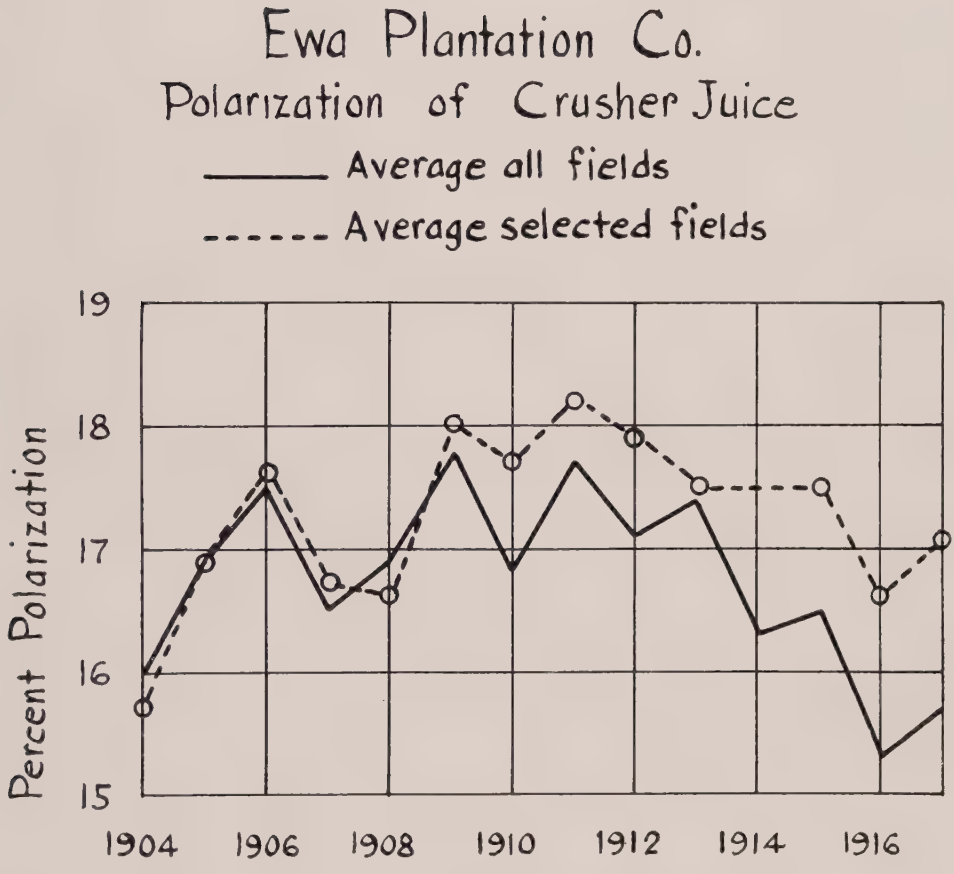

Ewa Plantation Co.
Polarization of Crusher Juice
Average all fields
Average selected fields
Percent Polarization
19
18
17
16
15
1904
1906
1908
1910
1912
1914
1916

Fig. 3

Ewa Plantation Co.

Co-efficients of Correlation between Polarization of Crusher Juice and (A) Mean monthly maximum temperature
(B) Mean monthly minimum temperature

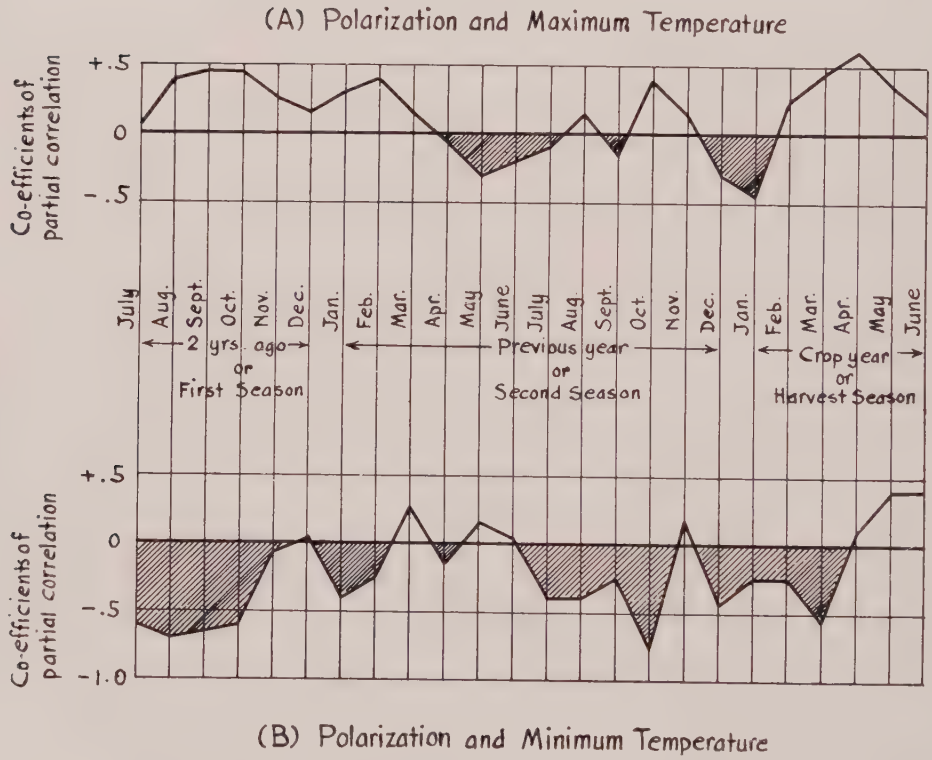


Fig. 4

Ewa Plantation Co.

Seasonal Temperature Conditions Essential For High Polarization Of Juice As Interpreted From The Trend Of Values Of Correlation Co-efficients

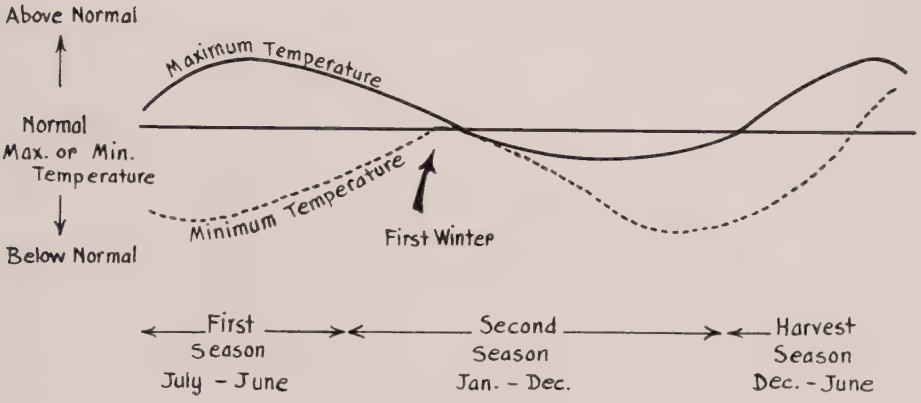


Fig. 5

Ewa Plantation Co.

Co-efficients of Correlation between Polarization of Crusher Juice and (A) Number of clear days in a month (B) Number of cloudy days in a month

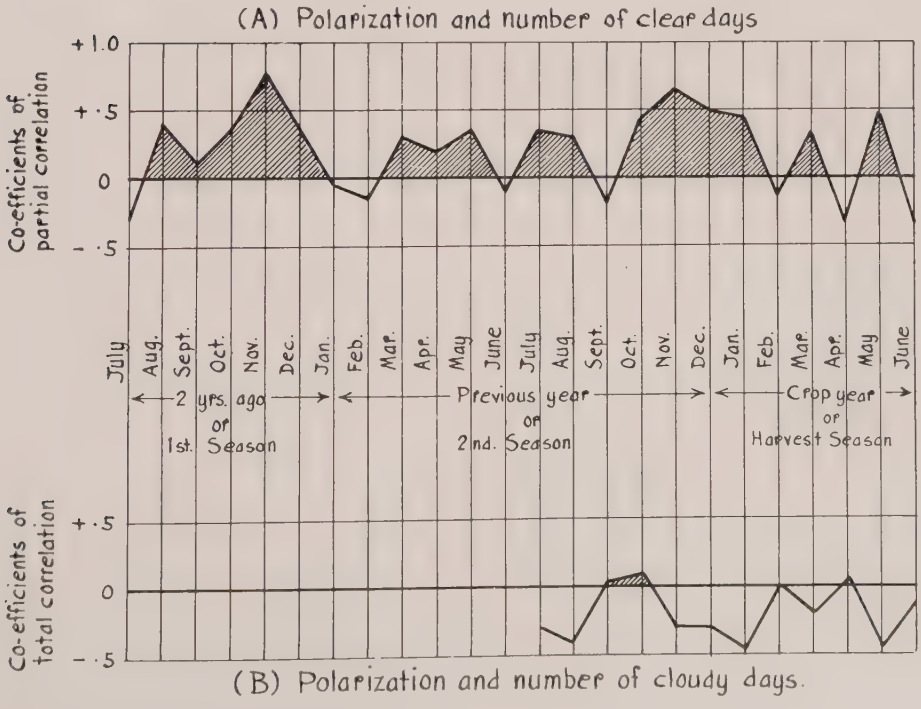

(A) Polarization and number of clear days
Co-efficients of partial correlation
+1.0
+.5
0
-.5
July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June
2 yrs. ago or 1st. Season
Previous year or 2nd. Season
Crop year or Harvest Season
Co-efficients of total correlation
+.5
0
-.5
(B) Polarization and number of cloudy days.

Fig. 6

Ewa Plantation Co.

Purity of Crusher Juice of Selected Lahaina Fields Compared to the Average Purity of All the Fields of the Plantation.

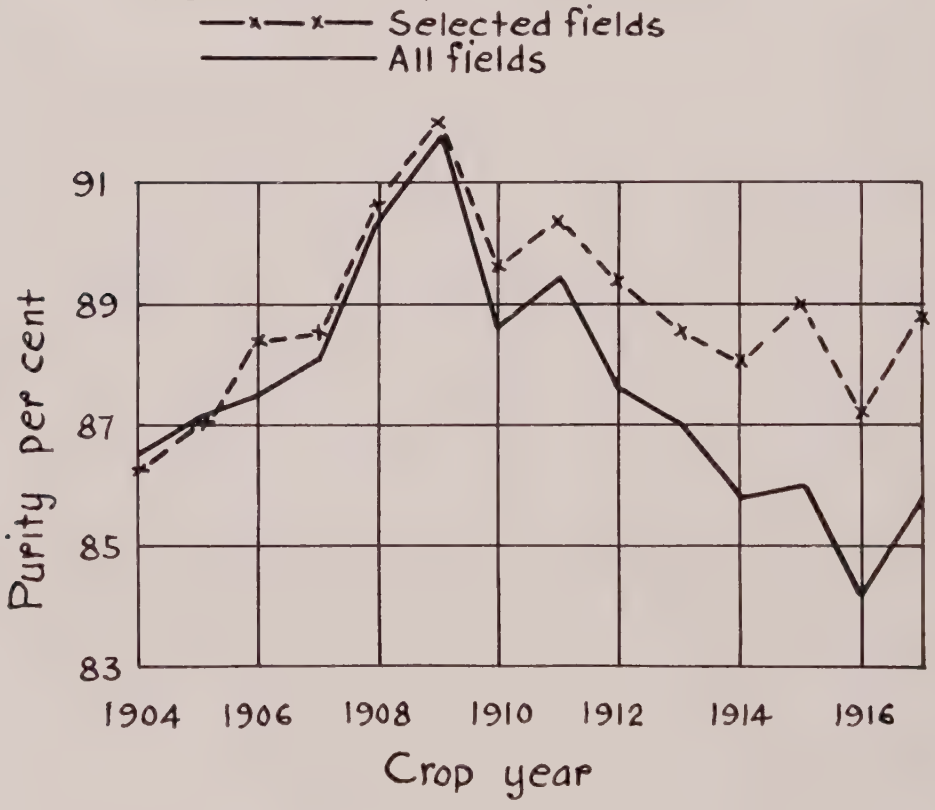


Fig. 7

Ewa Plantation Co.

Co-efficients of Correlation between Purity of Crusher Juice and (A) Mean monthly maximum temperature (B) Mean monthly minimum temperature

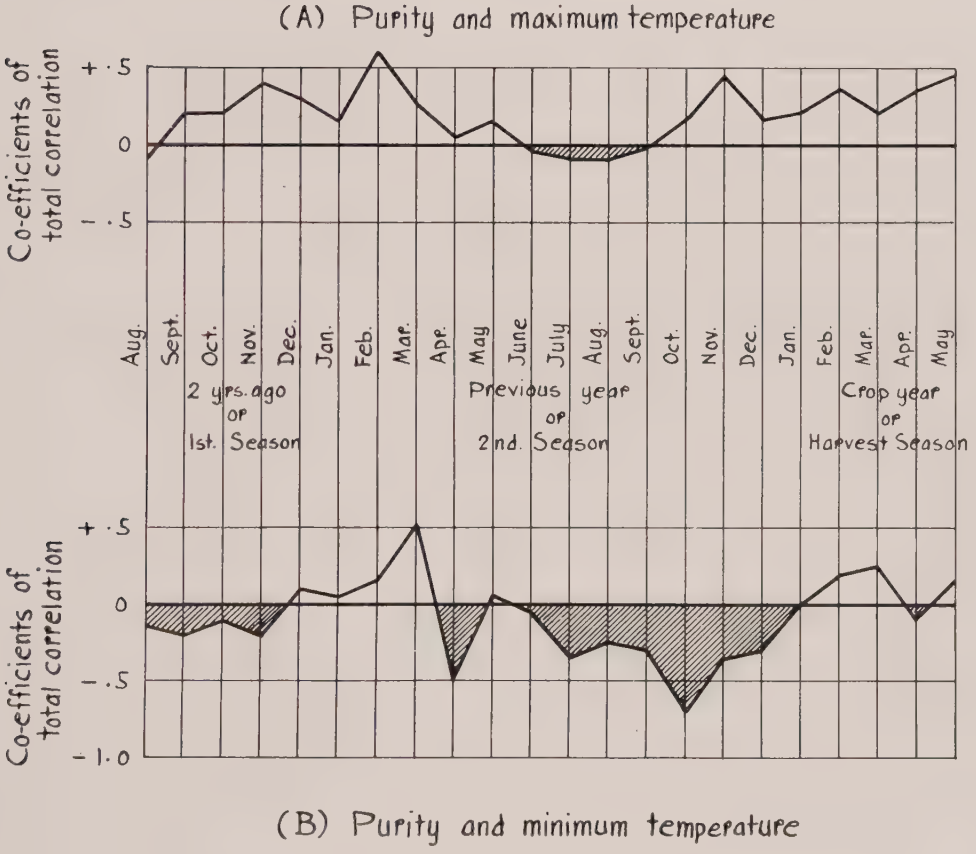
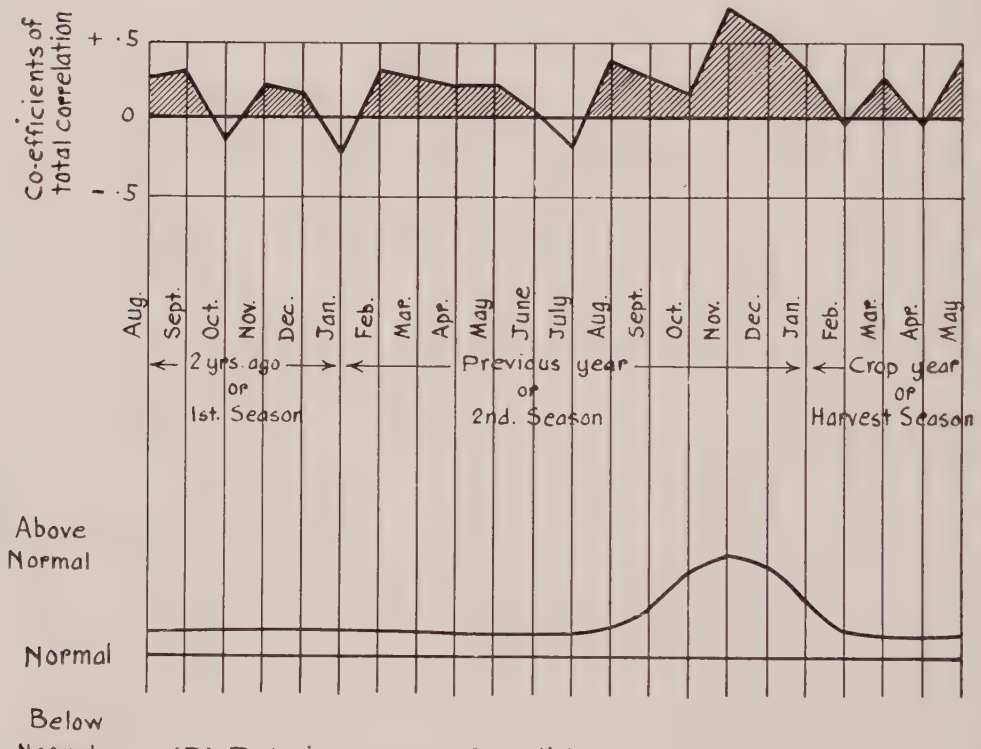


Fig. 8

Ewa Plantation Co.

Co-efficients of Correlation between Purity of Crusher Juice and Number of Clear Days in a Month

(A) Purity of crusher juice and clear days.



(B) Relative amount of sunlight necessary in the different seasons for optimum conditions - a simplified presentation of the upper curve.

Fig. 9

Ewa Plantation Co.

Relationship between the Purity of Crusher Juice this Season and the Number of Clear Days in Nov. of the Previous Year.

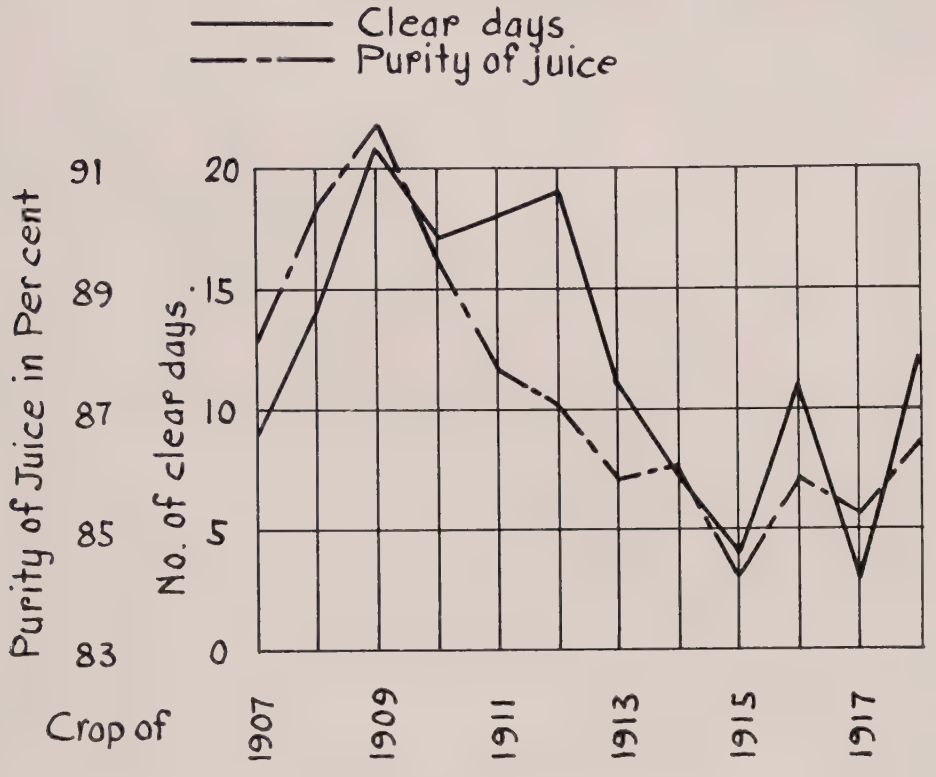


Fig. 10

Ewa Plantation Co.

Relationship between the Purity of Crusher Juice this Season and the Number of Clear Days in the Previous Year

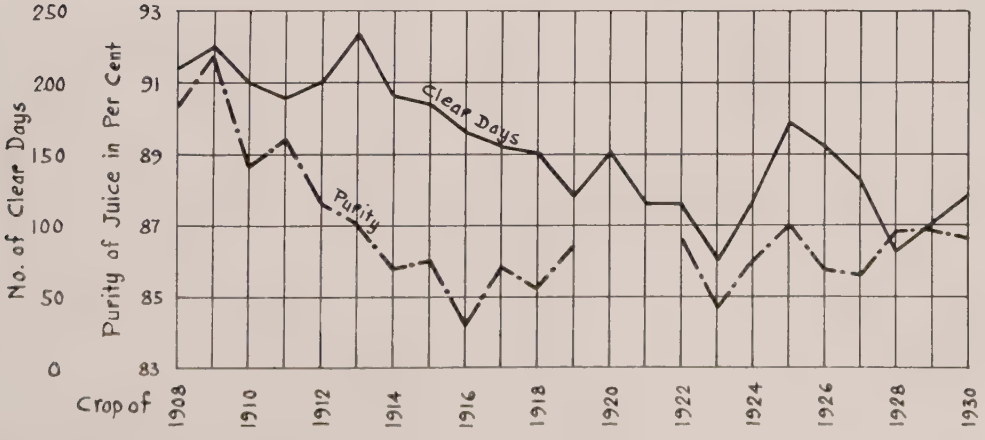


Fig. 11

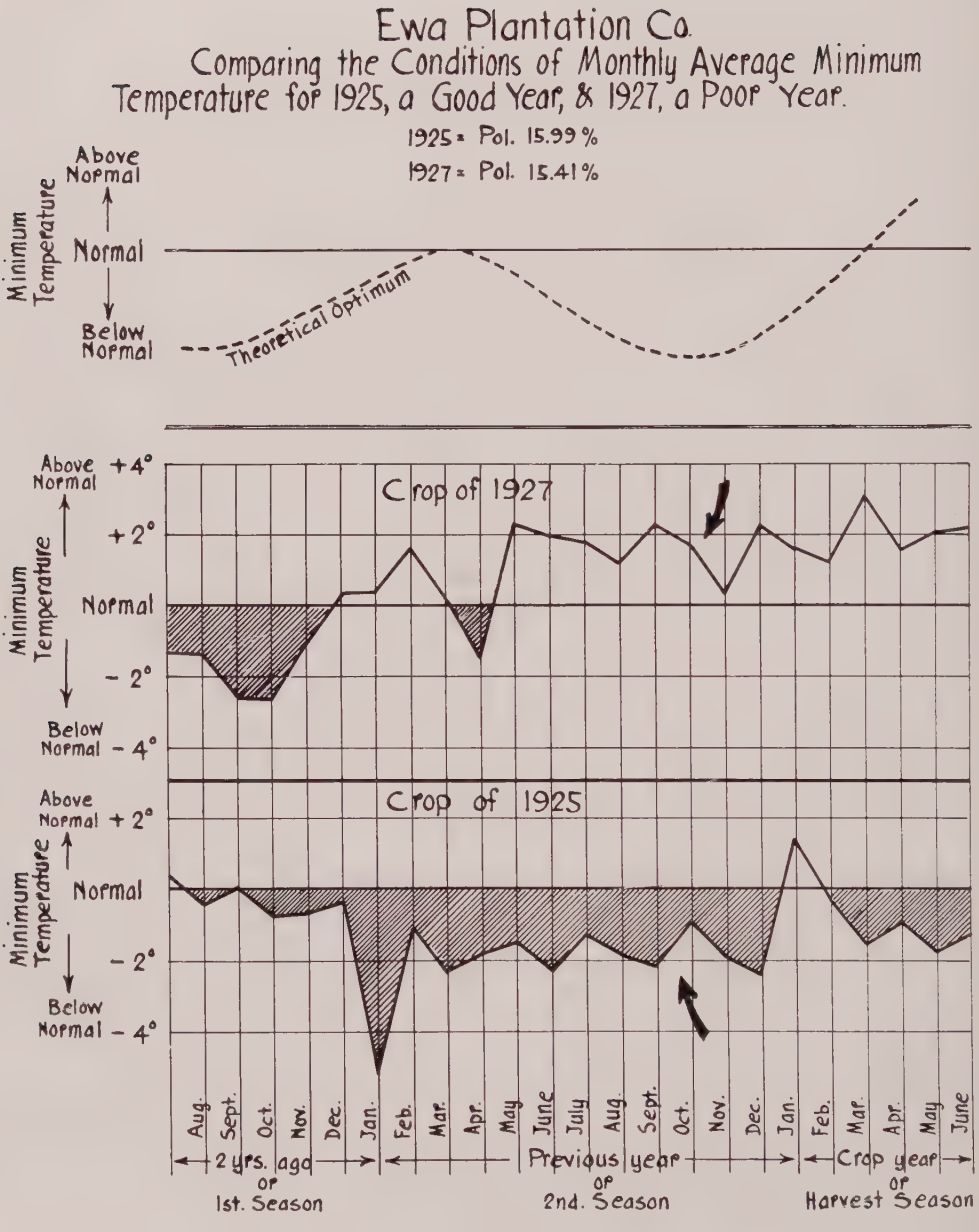

Ewa Plantation Co.
Comparing the Conditions of Monthly Average Minimum Temperature for 1925, a Good Year, & 1927, a Poor Year.
1925 = Pol. 15.99 %
1927 = Pol. 15.41 %
Above Normal
Minimum Temperature
Normal
Below Normal
Theoretical Optimum
Above Normal +4°
+2°
Normal
-2°
Below Normal -4°
Crop of 1927
Above Normal +2°
Normal
-2°
Below Normal -4°
Crop of 1925
Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June
2 yrs. ago
Previous year
Crop year
1st. Season
2nd. Season
Harvest Season

Fig. 12

Ewa Plantation Co.
Number of Clear Days During the Growth Period of the Crop of 1925 Compared to that of the Crop of 1927.

1925 = Purity 86.95 %
1927 = Purity 85.57 %

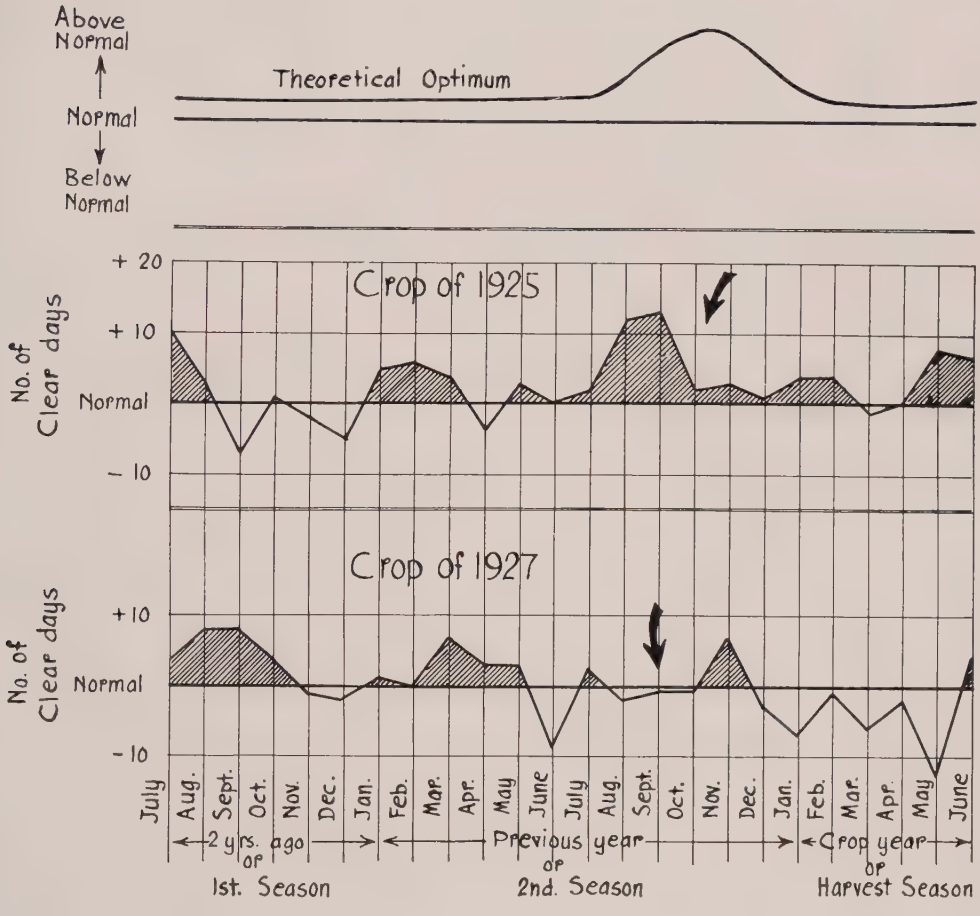
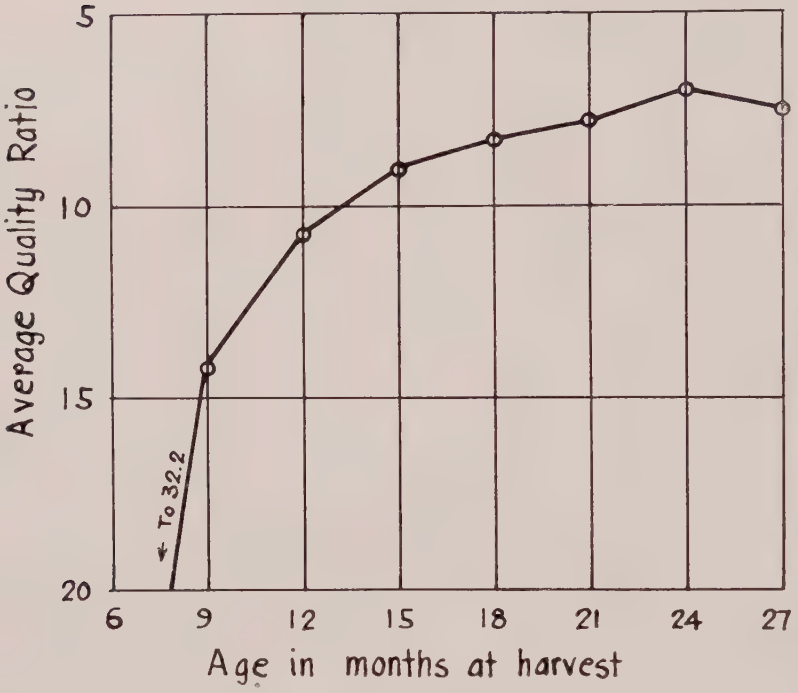


Fig. 13

(A) WAIPIO EXPT. E

Average Quality Ratio of H103, Plant, Harvested at Various Ages - Average of Crops Started in Different Seasons.



(B) PAAUHAU SUGAR CO. - GROWTH EXPT.

Volumetric Rate of Growth of Cane of Various Ages. (Field 4A - D1135, long ratoons, irrigated)

The Problem of Juice Quality

By U. K. Das

Foreword

At this time of the year, our inquiries turn naturally to the problem of juices. For almost two years, the crop has been growing in the field. We have given it all the care and attention that we were capable of; the stand of cane in the field had raised hopes of an excellent yield, but now that the field is harvested, we find cause for disappointment. Owing to the poor quality of juice, the yield of sugar is not as high as we had hoped it might be.

We feel sure that the quality of juice is not just a matter of chance but that it is the effect of certain definite causes.

Introduction

Twenty years ago the Territory produced about 37 tons of cane per acre and obtained therefrom about 4.70 tons of sugar. In 1930, we obtained from the same fields an average of 59 tons of cane per acre and about 6.80 tons of sugar. In twenty years we have raised our cane yield 60 per cent, but our sugar yield only 45 per cent. Obviously we have not been getting as good a quality of cane in recent years as we used to. Fig. 1 shows that this deterioration of the quality of juice is not an accident of the last year but that it has been progressing steadily during the last twenty years. As our cane yield has been increasing our juice quality has been going down. The question of juices becomes a matter of the greatest concern when we realize that could we have maintained the quality of our cane, the Territory would have produced about 1,007.500 tons of sugar last year.

Why has the juice been deteriorating? Is it because of soil, climate, because of something we do now that we did not do before? These questions can be answered only when we know how sucrose is accumulated in cane and the factors that influence this process.

The following pages bring together in an outline form information from various sources on the subject of sucrose formation in cane.

The Sugar Cane and Its Environment

We may think of the sugar cane plant as a manufactory where the leaves are the machinery with which sugar is made, the cells of the stalk as the storehouse in which sugar is stored, carbon dioxide, moisture and plant food as the raw materials. Then the total output of sugar will depend on the amount and quality

of raw material, the capacity and efficiency of the manufacturing units and the capacity of the storehouses. But subordinating these three conditions, there are two others, namely (a) the element of time—no matter how efficient the machinery is, only a certain amount of material can be made into finished goods in a given time; and (b) the environmental conditions. As this manufactory is situated out in the open, it is subject to all the vicissitudes of weather, which regulate the efficiency of the machinery, the amount and quality of raw materials and even the number of working hours.

The Sugar Cane Plant—General Considerations

In a very young cane there is very little sugar of any kind. As the cane grows sugars begin to accumulate; at first there is more glucose than sucrose, but as the cane reaches maturity sucrose predominates so that a ripe cane contains only a very small proportion of glucose. (Incidentally this phenomenon finds a practical application in the determination of the ripeness of a cane.) The process of sucrose accumulation, is therefore, intimately related to the process of growth. Hence, we would be quite safe in stating that whatever affects the processes of growth also affects the process of sucrose formation in cane. Observations indicate that the more rapid the growth of cane, the less rapid the formation of sucrose and *vice versa*. But there is no evidence to show that there is a cause and effect relationship between the two. It would perhaps be more correct to say that factors that inhibit rapid growth, promote ripening.

Sucrose is elaborated by the cane leaves and stored in the parenchyma cells of the nodes and internodes.

The following figures from Geerligs (1) (p. 94) show that the internodes contain more sugar than the nodes, because the internodes have a larger proportion of parenchyma cells. Other things being equal, canes having more internodal space are likely to have higher sucrose content than canes with more nodal space.

		Sucrose Per Cent Cane
1	Fibrovascular bundles	15.63
	Parenchyma cells	18.88
2	Nodes	15.5
	Internodes	17.5

If a well-developed cane is cut into three segments, top, middle and bottom, it will be found that the bottom part contains the most sucrose. As the cane advances to maturity this zone of the highest sucrose content moves upwards and in an over-ripe cane it may be located more towards the middle.

Venkatraman and Row (2) (India) give the following figures:

Joints	Polariscope Reading	Approximate Polarization*
Basal 3 joints	— 33.6	8.2
Next 3 joints	— 50.0	12.3
Next 3 joints	— 63.2	15.3
Next 3 joints	— 75.8	18.4
Next 3 joints	— 86 2	20.5
Next 3 joints	— 87.6	20.8
Four joints above dead leaf	— 71.4	17.2

* The polarization figures are supplied by this writer.

Every joint of a sugar cane carries a leaf; the question, then, arises: Can there be any increase in the sucrose content of a joint after the leaf attached to it has died? The work of Kuyper (3) in Java proves that the process of sucrose accumulation does not necessarily stop with the drying out or dying of a leaf. In most of these experiments the sucrose content of a joint went on increasing steadily even after the leaf attached to it had fallen off. (See Fig. 2.) Geerligs (1) (Java) writes:

> At last the joint has reached the period in which the leaf to which it belongs has ceased to assimilate and is dying off. Now the quantity of sugars in the joint increases by the portion which flows to it from the higher parts of the cane and thus is not fixed by the higher joints. As the distance of the joint from the assimilating leaves becomes larger, owing to the death of more and more leaves, the increase in the sugar content grows less until finally we reach the point where the influx of sugar into the joint is totally stopped, but owing to assimilation by the chlorophyll of the rind, the joint gains a little sucrose; however, this profit is more than counterbalanced by the loss of reducing sugar by respiration.

As the parenchyma cells serve as storehouses for sucrose, the manner in which these cells are formed is of the highest importance. Geerligs (1) (p. 85) says:

> If the circumstances of growth and development have been very favorable, the storage accommodation for sugar in the cane stalk is very spaciously built; a great deal of sugar may, therefore, be accumulated in the cells, without the liquid in the cell becoming as concentrated a solution as is the case in cane grown under less favorable conditions where less parenchyma cells are present.

Quintus (4) (Java) says:

> We have seen that sugar formation takes place in the leaves while the parenchyma cells of the stem serve as depositories for saccharose. It is of great importance how these cells, in which sugar is eventually stored, are formed. The cells should be able to form and develop undisturbed, which can only be the case when growth proceeds regularly.
>
> Hence the sugar percentage depends not only on the progress of the monsoon, as we saw before, but also on the manner in which the tissue has been formed, thus also on the manner in which the plant has grown.
>
> The more regularly and normally growth has proceeded, the greater will be the accumulation of sugar.

Location

The location of a place determines to a great extent how a cane variety will grow and ripen under the particular climatic conditions. The seasonal differences in temperature, hours of daylight, length of the growing season, all reflect on the sucrose content of cane. Continental or insular climate have also a bearing on juices. An insular climate will have less range of temperature between day and night and between seasons than a continental climate.

Likewise, elevation has a great influence on sucrose content. Other things being equal at higher elevations cane grows slowly but possesses a high percentage of sugar.

Quintus (4) (p. 7) says:

> Besides rainfall elevation above sea level affects the formation of saccharose. In a cool climate more sugar is formed because the cane grows slowly. On estates situated at a high elevation, less cane is always produced, which disadvantage is partly or wholly made up by a greater sugar per cent.

Geerligs (1) (p. 85) says:

> On plantations situated considerably above sea level the low night temperatures stop the growth and promote ripening.

Herewith is presented a climatic map of these Islands. (Fig. 3.) A study of this map would bring out that the plantations having poor juices like Kaeleku Sugar Company and Waimanalo Sugar Company are windward plantations having a low daily range of temperature. On the same map, as we move towards the left, the differences between the day and night temperatures increase and we encounter the plantations that usually obtain good juices. It will, further, be observed that the plantations having a high range of temperature are our leeward plantations. These plantations have not only this advantage of favorable temperature conditions but they are also favored in the matter of sunshine.

The reason for the differences in the average quality of juice of our plantations may, therefore, be largely attributed to their location.

Variety of Cane

Some canes have normally a high sucrose content. This may be due to some morphological characteristics of the variety, or due to the size, color, texture, efficiency, etc., of the assimilating leaf surface or the storage cells. There is a popular belief in some parts of the world that a yellow to orange colored cane gives a higher sucrose content than cane of any other color. There is no experimental evidence to support this belief. It would, however, be worth while to know if the color, size, etc., of the leaf has anything to do with the sucrose content of a cane.

Some varieties mature early, that is, they will reach maximum sucrose content early in the harvesting season, while those that mature late, will reach it later in the season. This may be due to the inherited qualities of the cane or its feeding habits.

Climate

Of all the factors influencing the sucrose content of a variety, climate is probably the most important. Sunshine, temperature, rainfall, humidity, wind, all of these vitally affect the growth processes of the cane plant. In spite of our best efforts, the sucrose content of our cane varies from year to year due more to weather conditions than to any other single factor. If we study Fig. 4 we will see that the fluctuations in the average quality ratio of the four islands of the Territory are very similar from year to year—this in spite of soil variations and different varieties of cane. Sir A. D. Hall (5), former head of the Rothamsted Experiment Station, says:

> Even on the Rothamsted plots, where the differences in the supply of nutrients are extreme and have been accumulating for fifty years, the composition of the grain changes more from one season to another than it does in passing from plot to plot.

I. A. Colon (6) (Porto Rico) writes:

> The last experiments of the Insular Experiment Station seem to indicate that climatic conditions have greater effects on the purity of the juices than the fertilizers applied.

Sunshine

Carbohydrates can be manufactured only in the presence of light. Light controls the chemical reactions of the leaf because it is essential *per se* and also because sunshine modifies the temperature of the air and the plant cells. No doubt the name "crystallized sunshine" as applied to sugar arose from observations that places with plenty of sunshine usually give canes of high sucrose content. Noel Deerr (7) (p. 27) says:

> A factor that has influence on the composition of the cane is that of direct sunshine as bearing on the process of change known as photosynthesis. This factor may reasonably be of some moment in the wetter districts and may account for the low percentage of sugar in canes grown in the equatorial rain belt.

Our studies (8) indicate that the amount of sunshine is of importance even in our dry, irrigated plantations. Fig. 5 shows that the purity of juice at Ewa from 1903-1917 bears a close relationship to the total number of clear days in the years 1902-1916, respectively.

The duration, intensity and also the quality of sunshine have influence on sucrose content.

Temperature

The great influence of temperature on the sucrose content of cane has always been recognized. Thus Geerligs (1) (p. 83) writes:

> In subtropical countries temperature has a very marked influence on the sucrose content of the cane. This has been shown for Louisiana by Browne and Blouin, in the results of years 1903 and 1904, which were very dissimilar as regards weather conditions.

	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Nov. 15
			1903		
Sucrose	2.70	5.97	11.27	13.60	15.86
Reduced sugar	3.80	3.68	2.51	1.02	0.63
Purity	36.00	57.02	76.72	87.85	92.10
			1904		
Sucrose	2.35	5.13	8.04	9.13	12.00
Reduced sugar	4.04	3.75	3.55	2.82	1.66
Purity	32.28	52.35	66.61	71.55	80.53

The weather of the two years was as follows:

		July	Aug.	Sept.	Oct.	Nov.	Dec.
Average daily temperature	—1903	82.80	82.10	77.0	67.90	58.00	49.00
	1904	80.90	84.10	84.20	71.20	64.30	58 40
Rainfall, inches	—1903	5.55	5.98	1.27	0.36	0.23	3.89
	1904	6.47	5.75	3.24	0.75	1.50	3 02

Ishida and Sawasaki (9) (Formosa) find:

> The coefficient of maturity is mainly influenced by atmospheric temperature during the maturing season so long as the season is dry. The relationship is inverse.

The same writers find that for each degree (centigrade) rise in temperature above normal during the ripening season, Rose Bamboo decreases in sucrose con-

tent by 0.478 per cent and for each degree fall in temperature below normal, the sucrose content increases by 0.946 per cent. Noel Deerr (7) (p. 25) writes:

> The temperature range has a very important bearing on the composition of the cane. In those places that have a uniformly high temperature and no cool season, an impure cane of low sugar content and high in reducing sugars is almost invariably harvested. In such a case there is opportunity for continuous vegetative growth and the crop as it reaches the mill will consist of canes in full vegetative vigor, of ripe and of over-ripe canes. In extra-tropical climates, as in Louisiana, the limited period of growth affords a cane that does not have an opportunity to reach maturity.

Koenig (10) (Mauritius) finds that the sucrose content of cane is inversely related to mean air temperature of the ripening season and in his opinion:

> The calculation of the probable sucrose content of cane at least for typical localities of the colony could be performed with sufficient accuracy for practical purposes if more extended series of temperature observations and especially of observations of the moisture content of the soil were available.

McDonald (11) (Louisiana) found that low temperature in the fall months prior to harvest tended to slightly improve the sucrose content of cane. But during the actual harvesting period warm conditions were essential. Most of the writers referred to mention the influence of temperature just prior to harvest, but our studies (8), (12), indicate that temperature conditions during the entire growth period of a crop are of moment to the sucrose content of cane. A statistical study (8) of the juices of the Ewa Plantation Company brings out that for high sucrose content the days should be warmer than normal during the entire life of a crop except in the second season summer and the late fall and early winter months of the harvesting season. The nights, on the other hand, should always be cooler than normal. These studies also point out that temperature conditions during the grinding season are of less moment than during the fall months prior to harvest.

Therefore, for ideal conditions we should have warm days and cool nights.

Van Deventer (13) (Java) observes:

> The rendement of cane grown a few hundred meters above sea level is, as a rule, higher than the one of cane grown in the lowlands. It is assumed that the low night temperatures which prevail in the higher altitudes aid the ripening of the cane more than any other single factor.

In the climate map of these islands, referred to previously, it will be seen that our poor-juice plantations have generally the smallest differences between day and night temperatures.

The complex processes involved in a ripening cane are still little understood but the following considerations may partly account for the distinct influences of day and night temperatures on the sucrose content of cane.

Temperature during the daytime controls the processes of assimilation, translocation and respiration of the plant. During the nighttime, the process of assimilation by which the leaf elaborates carbohydrates stops, but the other two processes still go on. The process of respiration causes a loss of material elaborated during the daytime; for some of the material is broken down to supply the energy for

the chemical reactions in the plant. Within certain limits, the higher the temperature the greater the respiratory activity of the plant. Now, if we consider the total matter stored in the plant as the difference between total matter assimilated and total matter lost by respiration (net gain equals amount assimilated minus amount lost by respiration) then, we can see that relatively high night temperatures will produce a greater loss of elaborated material and thus prevent the accumulation of a large amount of sucrose in the plant.

Blackman (14) quotes the following results of an experiment of Lundegardh's:

ASSIMILATION AND RESPIRATION PER HECTARE OF A POTATO FIELD

Assimilation	Respiration	Gain	Per Cent Gain
300 kilograms	175 (20° C.)	125 K. G.	100
300 kilograms	132 (10° C.)	168 K. G.	130

Thus a difference of 10° C. in temperature at night made a difference of 30 per cent in the total weight of matter gained.

Rainfall

In unirrigated places, rainfall is one of the most important factors influencing the sucrose content of cane. The total amount as well as its distribution are of importance.

Quintus (4) (p. 4) writes:

Sugar cane requires a fairly accentuated alternation of monsoons. It is necessary that a period of plentiful rain be succeeded by some months of dry weather, as otherwise the cane is unable to attain full maturity, so that a large crop of cane is indeed gathered, but the percentage of sugar is so small that the profit is inconsiderable, especially when selling prices are low. Likewise, the time when the dry period commences is of importance; if it arrives too late, the cane does not ripen completely; and this is also the case if the dry weather sets in too early; when the cane, moreover, dies prematurely.

As a rule some few rain showers at harvest time have no influence or cause only an apparent diminution of the sugar percentage, as the juice is diluted by the absorption of water without affecting the total amount of sugar.

Geerligs (1) (p. 84) says:

In tropical countries where the average temperature does not vary much in different years, the sucrose content of the cane is not so much influenced by the temperature as by the rainfall. Kobus (*Proceedings of the Eighth Sugar Congress*, Soerabaya 1907, 40) illustrated this in the table below:

		May-October Ripening Time		Oct., Nov., Dec. Soon After Planting	
	Sugar Extracted from 100 Cane	Avg. Monthly Rainfall	Inches per 1000 of Year's Total	Rainfall in 3 Months	Inches per 1000 of Year's Total
1894	10.36	2.16	127	23.62	368
1895	9.79	4.66	249	18.74	340
1896	10.55	0.74	51	17.60	310
1897	10.06	1.38	87	19.37	339
1898	10 21	3.46	185	27.95	417
1899	10.94	2.28	160	18.23	326
1900	9.57	4.56	263	17.72	288
1901	10.16	3.42	176	19.10	310
1902	10.77	1.10	67	11.85	96
1903	10.03	2.48	131	25.78	418
1904	10.74	3 07	174	20.59	347
1905	10.37	2.12	129	13.27	233
1906	10.04	3.11	184	26.61	396

Van Deventer (13) (Java) writes:

The earlier the west monsoon rains begin (at start of crop) the higher becomes the rendement and sugar yield; the yield of cane on the other hand is less influenced by this factor. If the rains are late in starting and the east monsoon (dry period) has been long, the effect is a low rendement and low sugar yield.

Drought not only lowers the cane yield but also the sucrose content. Geerligs (1) (p. 85) says:

Cane having had an abnormal growth owing to drought often ripens very rapidly; the ripening process proves to be very short, the cane soon becomes over ripe and loses in sugar content.

Our study (12) of the quality of juice at the Pepeekeo Sugar Company supports the statements just referred to. Fig. 6 shows that at Pepeekeo Sugar Company high sucrose content in cane is associated with plentiful rainfall during the growing season and dry weather for a few months immediately preceding and during harvest time.

Thieme (15) (Java) shows that if the weather is too dry during the growing season, then this will result in a cane of low purity at harvest.

The belief that a dry harvesting period is essential to high sucrose content is so firmly implanted in the minds of many that it is necessary to mention that this is not the case everywhere.

Geerligs (1) (p. 86) says:

A dry harvesting time is favorable for the ripening on an estate having moist low lying land, but unfavorable for estates on a loamy, easily-cracking soil, where the rootlets may be torn asunder, if the cane is not cut before the land has dried up.

Van Deventer (13) (p. 1) says:

For good maturity of the cane, a dry period is very desirable, but under no condition should this period start before the growth is nearly completed. If this is not the case, then the cane does not mature, but begins to die while still immature.

Other Climatic Factors

Somers-Taylor (16) (India) showed that the early and late ripening of the same variety of cane in succeeding years was correlated with the humidity of the air in the months preceding harvest. Low humidity in those months induced early ripening.

The question will naturally arise: Which has the more influence on the sucrose content of cane—sunshine, temperature or rainfall? All are of importance. In localities where rainfall is the more variable element from year to year sucrose content of cane will fluctuate more in accordance with rainfall variations but where rainfall is of no great consequence as in the case of our irrigated plantations, variations in temperature will surely reflect more on the composition of juice from year to year. The same consideration holds true in the case of sunshine. In other words, sucrose content will fluctuate with any of these principal factors that happen to be limiting at the time.

Soil

Both the physical and chemical composition of the soil affect the composition of the juice. In a porous or well-drained soil cane matures early, because the soil dries out quickly; on the other hand, a soil with a high water table or poor drainage loses moisture very slowly, vegetative growth can proceed for a longer time and as a result cane ripens very slowly and in extreme cases may never ripen fully.

Geerligs (1) (p. 85) says:

> Cane ripens slowly in a moist soil where it may continue its growth during a long period; on soils which are drying up in a dry season it will ripen much more quickly.

On a soil abundantly supplied with plant food, especially nitrogen sugar cane makes rank growth, may never stop growing and as a result cane of low sucrose content is sure to be harvested; such is often the case in virgin lands.

Noel Deerr (7) (p. 92) writes:

> Lime is credited with producing a sweet and pure juice in the West Indian adage: "The more lime in the field the less in the factory."
>
> Phosphates are also believed to affect beneficially the sugar content of the cane and potash is reputed to have the reverse effect.

Bonazzi (17) (Cuba) says:

> It is found that where cane is grown on limestone soil it had impurities which did not tend to the high production of molasses. Canes grown on soils of a siliceous origin, on the other hand, yielded high melassigenic juices.

The presence of a large percentage of common salt in the soil lowers the sucrose content and purity of juice.

Besides these important minerals in the soil, the presence in small amounts of such elements as boron, manganese, iron, aluminum, etc., may affect the juices by influencing the growth processes of the cane. Some of these like aluminum are definitely toxic to sugar cane; others may be found which are helpful. Experimental evidences on this point are, however, meager.

Agricultural Practices

We have seen that the sucrose content of cane depends on the locality, the climatic conditions and the type of soil. But the effect of any or all of these can be modified by agriculture. It behooves us, therefore, to know the effect of our agricultural practices on the sucrose content of cane.

Time of Starting:

Time of starting has a great influence on the sucrose content. Thus Booberg (18) (Java) writes:

> It appears that the highest rendement is found in areas that were planted in June and harvested in July, thus at an age of about 13 months. The harvesting time seems to have exerted a much smaller influence upon the formation of rendement than the planting date.

Fig. 7 gives the quality of juice of plants and long ratoons at Ewa Plantation Company started at different months of the year. Indications are that the ratoons started in the middle of the warm growing conditions of the summer months give the best juices.

Time of Harvesting:

That the season of harvest has a great influence on the quality of juice is well recognized in these islands. The experience of Java is somewhat different.

Booberg (18) (Java) says:

> Rendement did not vary considerably during the different harvesting months, very early harvesting was surely deleterious.

That there is a definite season during which cane tends to ripen, regardless of variety, age or location, is indicated by Fig. 8, which shows the average month by month quality of juice for the past 22 years. It will be observed that juice quality reaches a peak in May and June.

This is probably due to the seasonal changes in temperature and sunshine. The cool winter slows down growth and sets in ripening. This ripening process receives a stimulus with the advent of the dry season after March with its plentiful sunshine.

After the peak has been passed in May and June, the cane probably begins to deteriorate or new growth starts, both of which result in a loss of sucrose.

However, there are evidences to show that the cultural practices can modify this "season of optimum juice quality". We all know that short ratoons harvested as late as August and September give excellent juices. A study of Fig. 9 (*a* to *d*) will show that in the years 1908-1914, the best month to harvest cane was in April; in 1915-1920 it was in May and in recent years it is in June. This would lead us to conclude that most likely our field practices of today have deferred the maturity of cane by a month or two.

It is the opinion of this writer that by suitable cultural practices we may be able to lengthen this season of optimum harvest—particularly in the irrigated plantations where water is under control. In other words, this peak of the season need not be just one or two months long, it can very likely be increased to three or four months.

Plant vs. Ratoon:

Geerligs (1) (p. 88) says:

> Ratoons generally have a better sucrose content than plants.

In countries like India ratoons are known to be richer in sucrose than plant cane. In Hawaii, on the other hand, plant cane appears to give better juices on the average than long ratoons.

This anomaly may be due to the fact that in Hawaii plant cane is favored in the sense that it is started and harvested at the optimum season and also it receives more care than the long ratoons.

In countries like northern India where the growing season is short, a ratoon

will have an advantage over plant cane, because it starts accumulating sucrose earlier than the plant cane and therefore can show more of it at harvest.

Age of Cane:

As has been said previously, no matter how efficient the machinery is only a certain amount of raw materials can be made into finished goods in a given time. Age of cane at harvest has, therefore, a great influence on the quality of juice. This point is brought out very conclusively in Fig. 10. The chart gains added significance from the fact that the figures for the quality of juice were obtained from cane planted in four different seasons of the year. It will also be seen from this chart that there is such a thing as a cane getting too old and juices deteriorating.

Suckering and Juice:

In a typical field of H 109 in our irrigated plantations there are 2 to 3 suckers to every original shoot. The amount and the manner of suckering, therefore, exercise a very great influence on the sucrose content of cane. If all the original shoots and suckers were ripe at the time of harvest, we would surely get good juices. But this is seldom the case, when the original shoots are ripe, the suckers may still be young and unripe. When the suckers reach maturity, the original shoots may have become too old.

In general, best juices are obtained where the suckers come out early and reach a considerable degree of maturity at the time of harvest.

Rodrigues (19) (Louisiana) found that early suckering was positively correlated with high sucrose content of cane.

Stubbs (20) (Louisiana) writes:

> With few exceptions, there has been a gradual diminution of sugar and of stalk from the original plants to the youngest suckers. This fact emphasizes the necessity of getting suckers as early as possible and after that cultivating to repress them.

Van Deventer (13) (p. 132) writes:

> If they (suckers) sprout late, then they are not ripe at the time of harvest and have very bad juices.

Width of Cane Rows:

Width of cane rows may have influence on juices, because wider rows give more access to sunlight and encourage suckering. However, the evidence so far seems to indicate that under field conditions, width of rows have little or no influence on the sucrose content.

Stubbs (20) (p. 91) writes:

> Experiments indicate that sucrose and glucose are fairly constant for shoots planted 6", 12" and 18" apart in 5 ft. rows.

The same writer says in another place (p. 103):

> In general the narrower the row the larger the yield of cane without injury to the sugar content or its purity.

Locsin (21) (Philippines) found very little difference in the quality of juice of canes planted in rows 3, 4 and 5 feet apart.

Rosenfeld (22) (Tucuman), on the other hand, finds that in Tucuman, Louisiana Purple gave better juices when planted in widely separated rows. These are his figures:

AVERAGE OF PLANT AND LONG RATOONS—PURPLE CANE
(Tucuman Experiment Station)

Width of Rows	Sucrose	Purity
5 ft.	10.7	76.4
6 ft.	12.2	80.3
7 ft.	12.2	82.4
8 ft.	13.3	84.2

Cross (23) (Tucuman) cites the results of recent experiments with P. O. J. 36 and P. O. J. 213. His results indicate that rows about 5 feet wide give the best juices. Increasing or decreasing the width is attended with loss of sucrose.

In this connection it should be remembered that width of rows can influence the sucrose content of cane only in the sense that it determines to a great extent the manner and the amount of suckering and accessibility of sunlight. In narrower rows the late suckers die in the struggle for existence, so that the crop consists of original shoots and early suckers. What handicap narrow rows offer in the matter of sunlight is counterbalanced by the greater age and maturity of the stalks. In wide rows, on the other hand, suckering proceeds late in the season, and consequently a considerable percentage of the suckers are young at the time of harvest. The advantages of more sunlight in the rows is offset by the immaturity of the cane. Most likely, this is the reason why width of rows appears to have so little influence on sucrose content.

Arrowing in Cane:

Observations in all parts of the world point to the conclusion that generally speaking arrowing itself does not lower the juice, if the cane is harvested at the right time. Observations in Java, however, indicate that in some varieties there may be some loss of sucrose due to flowering.

Of the variety Black Java, Geerligs (1) (pp. 71-73) says:

> Arrowing does not, however, affect the composition of the cane to any extent, as may be seen from the analyses.

VARIETY—BLACK JAVA

	*1		2		3	
	Arrowed	Not Arrowed	Arrowed	Not Arrowed	Arrowed	Not Arrowed
Pol of juice	19.3	18.8	19.43	17.93	19.11	19.61
Reduced sugar	0.42	0.44			0.57	0 49
Purity	90.6	92.8	88.3	87.9	90.6	89.14
Fibre on 100 cane	13.2	13.0				

* Numbers indicate different plantations.

Speaking of some P. O. J. varieties, the same writer offers the following:

With other varieties, arrowing appears to have a worse effect, as is shown in the following experiments by Van Vloten (Java Archief, 1896, 636).

	Sucrose	Purity	Glucose	Yield of Sugar Per Cent per 100 Cane
P. O. J. 36 —Arrowed	15.42	88.62	0.40	10.76
Non-arrowed	16.38	89.02	0.29	11 49
P. O. J. 100—Arrowed	20.15	94.60	0.22	15.20
Non-arrowed	20.55	95.14	0.21	15.60
P. O. J. 247—Arrowed	16.80	89.84	0.60	11.92
Non-arrowed	17.60	90.72	0.47	12.64

In Hawaii, Allen (24) reported that tasseled stalks of Yellow Caledonia had less sucrose and purity than non-tasseled stalks. On the other hand, Jennings (25) found that in D 1135 and H 109 the reverse was the case. Naquin (26) wrote of the present status of this question as follows:

The consensus of opinion is that tasseled canes if harvested right after tasseling may give as much, if not more, sucrose than untasseled cane. Delay in harvesting causes deterioration in tasseled cane.

Stripping of Cane:

In the earlier days stripping of cane was advocated as a means of letting more light and air into the cane rows and increasing the sucrose content of cane. All evidences prove that stripping has no influence on the quality of juice. Thus Van Deventer (13) (p. 397) writes:

Stripping has no influence on rendement though it lowers the yield of cane and sugar.

Eckart (27) says:

Juice of unstripped cane is practically the same as the juice of stripped cane.

Hilling-up:

In places where the cane is planted in the bottom of furrows and then hilled up, the time of hilling-up affects the sucrose content of cane. Thus Van Deventer (13) (p. 390) says:

Hilling-up at two months gave slightly better rendement than hilling-up at 3 months.

Fallen Cane:

In Hawaii, very little concern is felt over cane prone on the ground. In fact, with heavy fertilization and two years' growth in the field, very few canes will be able to stand erect; but in other countries fallen canes reflect to the discredit of the farmer. In the sugar cane tracts of India, the clumps of cane are tied together or supported by especially erected barriers to prevent the cane from falling, so great is the fear of losing sugar in the fallen cane. Fallen canes are looked upon with great disfavor in Java. Geerligs (1) (p. 73) writes:

When the cane falls, the sucrose and the quotient of purity decrease considerably. The fallen canes are heavier and longer than the standing ones from the same stools. On the other

hand, their sucrose and fibre contents are inferior, and their water and reducing sugar contents higher. These differences point to unripeness in the fallen canes which grow more rapidly but ripen more slowly.

Van Deventer (13) (p. 470) says:

The greatest disadvantage of recumbency consists in a lowering of the sugar content.

Further experiments in Java show a loss in sucrose and purity in all fallen canes whether the canes were shaded or not.

Fertilizers

Of all the agricultural practices affecting the quality of juice, the application of commercial fertilizer is perhaps the most important. In fact, fertilizers are the only agencies at our easy command through which we gain some mastery over the elements to which the crops are subject.

Nitrogen:

Nitrogen is the most widely used fertilizer for sugar cane. Nitrate of soda and ammonium sulphate are the two most popular, though the use of more concentrated artificial fertilizers like calurea are coming into greater use. Nitrogen is essential for the formation of protoplasm. The application of nitrogen stimulates production of leaves, darkens their color, and promotes the various vegetative activities of the plant. Recent studies by Gregory (28) show that while the application of nitrogen increases the leaf area, it does not increase the efficiency of the leaves as assimilating surfaces.

While nitrogen is a powerful weapon in the hands of the agriculturists, evidences indicate that unwarranted use of this weapon may actually cause harm. While heavy applications of nitrogen increase the yield of cane, they do not always increase the yield of sugar, due to the loss in the quality of juice. This loss is probably due to the fact that nitrogen prolongs vegetative growth and delays maturity. In Hawaii, heavy applications of nitrogen have come into question of late years and have been blamed for lowering the sucrose content of our cane. Fig. 11 is reproduced from the Annual Report of the Experiment Station for 1930, showing the loss in the quality of juice due to increased applications of nitrogen. Alexander (29) finds an average loss of 2 per cent of sucrose for each application of 50 pounds of nitrogen over 150 pounds at Ewa Plantation Company. In the opinion of this writer, nitrogen may not be responsible *per se* for the deterioration of our cane juices. This will be clear from the following considerations:

Physiologists tell us that in the formation of new protein material, such as leaves, tissue, etc., the nitrogenous amino acids brought up by the roots combine with the carbohydrates elaborated by the leaves. Naturally the greater the amount of nitrogen conveyed by the roots, the more will be the requirement of carbohydrate. As a result, comparatively small amounts will be stored by the plant as sugar. By applying a heavy dose of nitrogen we are increasing the storage capacity of the plant but leaving less to be stored. The result is that we are harvesting cane low in sugar.

These considerations appear to suggest that if we could increase the assimilating efficiency of the leaves or if we allowed the sugar cane plant sufficient time to store sugar and mature after it had used up all available nitrogen, we would very likely harvest cane of good juice. In other words, application of nitrogen delays maturity but does not lower the juice on account of any particular quality that it possesses.

Thus Geerligs (1) (p. 85) writes:

> Fertilization with nitrogenous manure influences the growth of the cane and therefore likewise its sugar content. This influence does not act in a direct manner but rather in an indirect one, since such fertilization may retard or prolong the vegetative period. If the fertilizer has been applied late or a long acting manure, such as filter press mud or dung has been used, the growth does not cease and ripening will be retarded.

Noel Deerr (7) (p. 50) writes:

> There is a widespread belief that heavy manuring adversely affects the quality of the juice of the cane, and under certain conditions this may be correct; thus in a district such as Demerara, where a short period of growth obtains, a late manuring results in an impure juice. Possibly in such a case not only is the maturity of the crop delayed, but a second growth of young cane is stimulated and the comparison may become one of immature and mature cane. Again with heavy manuring there is a consequent increase in the size of the crop with less access of direct sunshine, and a delayed ripening is the result.
>
> On the whole, the writer (Noel Deerr) thinks that the bulk of the evidence points to weight of cane only as being affected; differences which may from time to time be observed are probably due to different degrees of maturity or to other uncontrollable factors vitiating the comparison.

Earle (30) (Porto Rico) writes:

> In the literature statements will often be found that while one can increase tonnage by the use of fertilizers, these do not affect sugar content. Other writers caution that fertilized cane will be less rich in sugar than that which is not fertilized. Both of these sets of writers ignore the fact that sugar content is more dependent on ripeness than on any other one factor.
>
> Where fertilizers are applied late, especially the slow-acting organic fertilizers, the tendency is to force growth late in the season, thus preventing early maturity.

Somers-Taylor (31) (India) says:

> It may be stated that such a top dressing of manure appears to weaken the juice of the sugar cane at the beginning stages of coming to maturity and delays its actual ripening for about a fortnight but that it is only a delay, and not a prevention of ripening, as in the case examined the treated plots appear to have given juice of almost the same richness as the blank plots. The only difference being that the stage of maximum maturity was reached a fortnight earlier in the case of the plots which did not receive a top dressing.

A study of the fertilizer practices of these islands tends to confirm what seems logical from a theoretical point of view and also what appears to be the consensus of opinion among the leading sugar cane techonologists of the world.

The illuminating Fig. 12 was published by Naquin in 1910, to show that the effect of heavy applications of nitrogen (up to 180 lbs.) was simply to retard maturity. The following excerpt is from Naquin (32):

It may be well to keep in mind that there is every reason to believe that any fertilizing material which will increase the yield of cane will have a proportional depressing action on the quality of cane until such time when other factors set in and mature the cane, at which time no noticeable difference exists between differently treated cane.

Plots receiving 180 pounds nitrogen reached maturity later, at which date all the treated and untreated plots had the same juice.

That under certain conditions large amounts of nitrogen may be applied without adversely affecting the quality of juice, is shown very clearly in a recent experiment at Honomu Sugar Company (Experiment 44, 1931 crop, D 1135, 23 months old, last application of nitrogen 13 months before harvest). The results show that there is not only no loss in sucrose due to an application of 240 pounds nitrogen per acre but that there is actually an increase over an application of 140 pounds of nitrogen.

RESULTS

Pounds Nitrogen	Q. R. (Tons Cane per Ton Sugar)
140	10.21
190	9.14
240	9.25

Fig. 9 (*a* to *d*), referred to previously, appears to support our contention that the increasing applications of nitrogen simultaneously with a decrease in crop length are delaying the maturity of the cane in these islands and the progressive deterioration of juices may be due more to this one factor than any other.

It will be observed in these illustrations that in 1908-1914, canes harvested in April gave the best quality of juice; in 1915-1920, it was in May and in recent years the best juices are being obtained from canes harvested in June. In other words, the optimum maturity of our cane comes two months later now than it did in 1908-1914. Varietal or climatic changes do not account for this delay of two months and we are forced to think that this shift is due to the enormous increase in the amount of fertilizers that are being applied today as compared with 10 or 20 years ago.

That sugar cane is not the only plant to react in this manner to nitrogen will be clear from the following statement of Sir A. D. Hall (5), former head of the Rothamsted Experiment Station in England:

As the amount of available nitrogen is increased the development of leaf and shoot increases, their green color deepens, and maturity becomes more and more deferred, so that a crop grown on land over-rich in nitrogen always tends to be late and badly ripened.

The question then arises: If heavy applications of nitrogen defer maturity, could we get good juices by leaving the cane longer in the field?

Alexander (29) finds that the depressing effect of nitrogen on juices is not offset by longer crop length.

Van Deventer (13) (p. 422) says:

The difference in rendement caused by too heavy or too little fertilization cannot be eliminated by leaving the fields standing for a longer period.

The evidences, therefore, indicate that though theoretically we should expect better juices from a greater crop length, in practice it does not always work that way. This is probably due to two reasons: (a) the season of the year—all canes tend to give better juices at certain seasons of the year, irrespective of crop length or treatments; and (b) canes of varying ages in a crop—if the crop stands too long, then, some cane will have passed maturity and started deteriorating. The profitable crop length from the point of view of juice quality will, therefore, be different in different localities, with different varieties and under different cultural and environmental conditions. The question of crop length in connection with nitrogen application is one that deserves careful and detailed study from our investigators.

There are possibly other ways of offsetting the depressing effects of nitrogen on the quality of juice, such as the time of application or the application of other plant foods together with nitrogen. These points are discussed in another place in this report.

At this point the question may naturally be asked: Does heavy fertilization cause any harm to the anatomy of the sugar cane plant? Do the cells become deteriorated or less efficient? Quintus (4) (p. 84) offers the following answer:

> If growth is artificially accelerated by too much manure or water the consequence is that fewer cells are formed, because cell distension has already set in before division is altogether over; and that the cells overgrow their strength because of which the chances of the tissue becoming spongy are greatly increased. Becoming spongy means death, so that the tissue may be regarded as lost for the storing of sugar.

We do not know of any experimental evidence in support of the above statement.

Phosphoric Acid:

Phosphoric acid is reputed to hasten maturity in grain and cereals. In sugar cane literature there is very little information on the effect of phosphates on juices.

Sanyal (33) (India) writes:

> Superphosphate has the greatest influence in producing a juice with the highest purity and sucrose content.

Cross (34) (Tucuman) thinks that the application of phosphoric acid may induce early maturity in plots heavily fertilized with nitrogen.

Deerr (7) (p. 92) says:

> Phosphates are also believed to affect beneficially the sugar content of cane and potash reputed to have the reverse effect.

Verret (35) thus sums up the local experience:

> Applications of P_2O_5 have no effect on juice quality.

Potash:

Potash is known to be essential to the formation of carbohydrates. As sugar

cane plant is primarily a storehouse for carbohydrates, it would appear that potash applications ought to improve juices.

There is much difference of opinion in the literature on this subject.

Alexander (36) writes:

Potash fertilization has increased cane yields at Ewa Plantation Company. This increase in cane yield was often accompanied by an improvement in sucrose content.

Conant (37) says:

At Olaa there have been instances where potash derived from muriate of potash when applied at the rate of 200 pounds K_2O per acre with the first dressing of fertilizer on Yellow Caledonia not only gave an increase in cane yields over 150 lbs. K_2O per acre but apparently improved the juice quality as well.

This improvement is probably met with only in certain areas for Verret (35) in averaging the results of fertilizer experiments comes to the conclusion that generally speaking applications of potash have no influence on juices.

Other Chemicals:

Liming the soil is known to improve the juices in certain countries like the West Indies; local experience has shown no gain from liming soils.

Traces of certain chemicals in the soils are believed to influence crop growth and quality.

Thus Pestana (38) (Brazil) found that applications of a small amount of manganese together with complete fertilizer gave better sucrose and purity than complete fertilizer alone.

Time and Number of Applications:

Another aspect of fertilization that has a great effect on the quality of juice is the time and number of applications. This question of time not only involves the season of application but also the age or stage of development of the cane at which the fertilizer is applied.

Experiments in Hawaii point to the conclusion that the best juices are generally to be obtained when the fertilizers are applied early and a sufficient interval is allowed between the last application and the time of harvest.

Verret (39) in reviewing experiments on this subject says:

We are very strongly convinced that we can very materially improve our juices and increase our yields of sugar by early intensive fertilization. This means applying all the fertilizer within six months.

The following example bears out this conclusion very forcibly:

PIONEER MILL CO. 1927 CROP—EXPERIMENT 56

[Planters' Record XXXI]

Plots	Fertilization—Lbs. Nitrogen					Total Lbs.	Q. R.
	June, 1925	Sept., 1925	Nov., 1925	Feb., 1926	April, 1926		
O	50	70	120	0	0	240	8.31
N	50	70	...	120	0	240	8.74
Q	50	70	60	0	60	240	8.72
P	50	70	60	0	120	240	8.81

The harmful results of continuing fertilization late in the season is shown by another experiment:

WAIPIO EXPERIMENT S—1921 CROP

Cane 21 Months Old
[Planters' Record, XXIV, p. 281]
270 Lbs. N Were Applied in 2, 4 and 6 Applications

Plots	Treatment	No. of Plots	Q. R. H 109
A	2 applications	28	8.48
B	4 applications	28	8.75
C	6 applications	28	8.89

Alexander (29) says:

> The key to profitable fertilization is application at the proper time. There is a point in the cane's growth when no further nitrogen or only small amounts can be applied with safety. Great care must be exercised in not giving the cane an overdose in the second season.

The feeding habit of the different varieties should also come in for consideration in deciding the proper time to apply fertilizer.

Kind of Fertilizer:

It is conceivable that the effect of a fertilizing element, nitrogen, phosphoric acid, etc., may vary with the ingredients from which these are derived.

Results of many experiments in Hawaii do not show any difference between nitrate of soda and sulphate of ammonia on the quality of juice.

There is also no evidence as yet that the forms of P_2O_5 and K_2O in present use in Hawaii differ in their effect on juices.

In sugar beets, however, it has been noted that sulphate of potash and muriate of potash give juices of different quality. Schreiber (40) (Belgium) found the following results:

Crop—Beet	Sugar Per Cent
Without potash	12 80
With sulphate of potash	14.20
With muriate of potash	15.30

Availability, Mode of Application, Etc.:

The effect of a fertilizer will depend on its availability and availability in turn may depend on the mode of application.

Fertilizer Balance:

A great deal of interest has recently been shown on the subject of proper balance of fertilizers. Some investigators have claimed that the harmful effects resulting from the use of one single fertilizer element may be corrected by giving adequate amounts of some other elements.

Thus Moir (41) states that the quality ratio is low not with the lowest or the highest nitrogen but with a balance of N, P_2O_5 and K_2O.

Cross (34) (Tucuman) says:

It is noted that the one-sided fertilization (ammonium sulphate only) results in a low purity cane. It is thought the purity of juice may be improved by the concurrent use of phosphates.

Colon (6) (Porto Rico) writes:

A heavy application of nitrogen to soils poor in phosphoric acid and potash results in a great foliage development without a corresponding increase in the growth of the cane, so, in order to obtain uniformly good results, the use of well balanced fertilizer mixtures is the best and safest method to follow.

Hach (42) (Porto Rico) thinks that "the real reason why too much nitrogen will reduce the sugar content of cane stalks" is due to lack of enough potash. The author suggests that every time we apply a dose of nitrogen we should apply potash with it and also make sure that there is plenty of available potash in the soil all the time.

Irrigation

Irrigation is one of the most powerful weapons in the hands of the sugar cane planters for the ripening of cane. Like rainfall, it must be well distributed in sufficient amounts to give the best results. In other words, there should be plenty of water when the presence of excellent weather conditions and abundance of plant food promote rapid growth. It should be less and less as the cane approaches maturity. If the cane plant does not have enough water when it is growing fast or has too much when it should be ripening, in either case a low percentage of sucrose will result. From these conditions, it follows that mere drying of the cane before harvest cannot ensure good sucrose content in cane.

Some data obtained from a previous study of the Ewa Plantation Company tend to show that the total amount of irrigation water has a close relationship to the quality ratio. (Fig. 13.)

Van Deventer (13) (pp. 382-383) says:

Experiments of Kobus and Schult show that sufficiency of water has a very favorable influence on sucrose content.

In another place the same author writes:

Sugar cane is a crop which needs very much water for its best development. As soon as there is lack of water, the cane is disturbed in its regular growth and stagnation takes place, which causes a lowering of the rendement and of the cane weight. There is also a danger in drying the cane too much by withholding water before harvest. Too much drying may result in raising the Brix only but the quality ratio may not improve due to loss in purity.

Verret (43) and others found that a non-irrigation interval of 40 days before harvest was as good, if not better, than an interval of 60 to 90 days. About the harmful effect of excessive drying, Geerligs (1) says:

As long as the cells remain alive, the composition of the juice does not appreciably alter,

but as soon as they die the reducing sugars increase at the cost of the sucrose. The chief cause of the death of the cells is the drying up of the cane.

The Salt Content of Irrigation Water Has an Effect on Juices:

Row (44) (India) found that plots irrigated with saline water invariably gave juices of low sucrose content and purity. Blouin (45), Eckart (46) and Maxwell (47) in Hawaii found conclusive proofs of the lowering of the sucrose content of cane from applying irrigation water containing more than 100 grains of salt per gallon. The following are a set of Eckart's figures:

	Quality of Juice		
Salt per Gallon of Water	Brix	Sucrose	Purity
None	20.28	18 90	93.20
200 grs.	16.46	14.40	87.50
200 grs.	16.56	14.50	87.60
200 grs.	15.89	13.80	86.80

Blouin (Hawaii) supplies the following:

Salt per Gallon of Irrigation Water	Sucrose	Purity
50 grs.	18.1	91.5
100 grs.	18.3	91.2
150 grs.	17.0	90.0
200 grs.	16.4	90.4

Miscellaneous Efforts to Induce Ripening:

The inverse relationship between growth and sucrose has always stimulated inquiries as to the feasibility of checking growth artificially and thus promoting maturity.

Eckart (48) in 1913 suggested the cultivation between the furrows of a ripening field as a means of checking growth by pruning the roots. An experiment on the subject yielded negative results.

In another place the same writer (49) advocated the application of phosphate fertilizers in a well-grown field of cane. His contention was that phosphate would check growth and hasten maturity. Experiments failed to confirm this view.

More recently some plantations are applying final molasses in their last irrigation water so as to help the field to ripen. The theory is that the withdrawal of nitrogen due to the bacterial action stimulated by molasses should induce ripening. The result of one experiment reported (50) did not show any gain in sucrose from applying molasses in the irrigation water. This particular phase of the problem is still being investigated and it appears to this writer that there are no physiological reasons why such a practice should not prove helpful.

Ripening is undoubtedly associated with the activity of the enzymes in the plant and theoretically it should be possible to stimulate the activity of the particular enzymes. The scope of such experiments as the one reported could very well be enlarged.

Diseases and Other Injuries

Cane attacked with diseases often shows less sucrose than healthy canes. Most likely, in the diseased canes the efficiency of the cells are impaired or there is an actual loss of stored sugar.

De Verteuil (51) (Trinidad) reports that there is a loss of 0.04 to 8.2 per cent on sucrose content of juice due to mosaic. Results, however, differ in different varieties and also in the kind of crop plant, ratoons, etc.

Geerligs (1) (p. 70) writes:

> Canes attacked by infectious diseases or by insects do not show such a regular distribution of the constituents as sound ones. Attacks of the cane borer cause the sucrose content to fall, while that of reducing sugar remains unchanged; the same effect being brought about by attacks from woodpeckers. Attacks by the top borer do not seem to affect the sucrose content, but the joints attacked may become infected with the pineapple disease or black rot, causing an increase of reducing sugars.

Hazelhoff (52) (Java) says:

> There is a loss of 26 per cent of available sucrose in joints damaged by striped stalk borer (*Diatraca venosata*).

Lee (53) reports the following losses in the quality of juice due to eye spot disease:

	(1) Pol	Purity	(2) Pol	Purity
Healthy cane	18.79	90.4	17.98	90.2
Diseased cane	12.16	75.1	14.53	85.3

Elliott (54) found that in certain districts in these islands the damage due to rats may bring about a considerable loss in the sucrose content of cane.

Summary

Briefly, then, what are the principal factors that influence the sucrose content of cane?

(1) The variety of cane.

H 109 or Badila will, generally speaking, give better juices than Uba or Kassoer.

(2) Weather conditions.

Bright sunny days and cool nights make for high sucrose. Cloudy days and uniform day and night temperature are associated with low sucrose. In wet districts, a dry ripening season is conducive to high sucrose.

(3) The season of harvesting.

In these islands there appears to be a tendency for cane to come to ripeness in April, May and June, regardless of other conditions.

(4) Nitrogen applications.

Heavy applications of nitrogen, especially in the second season appear to lower the quality of juice.

Injury by diseases, insects and rodents, the physical and chemical composition of the soil, irrigation practices, and many other factors, may influence sucrose content to a greater or less degree. These have been discussed in the body of the report.

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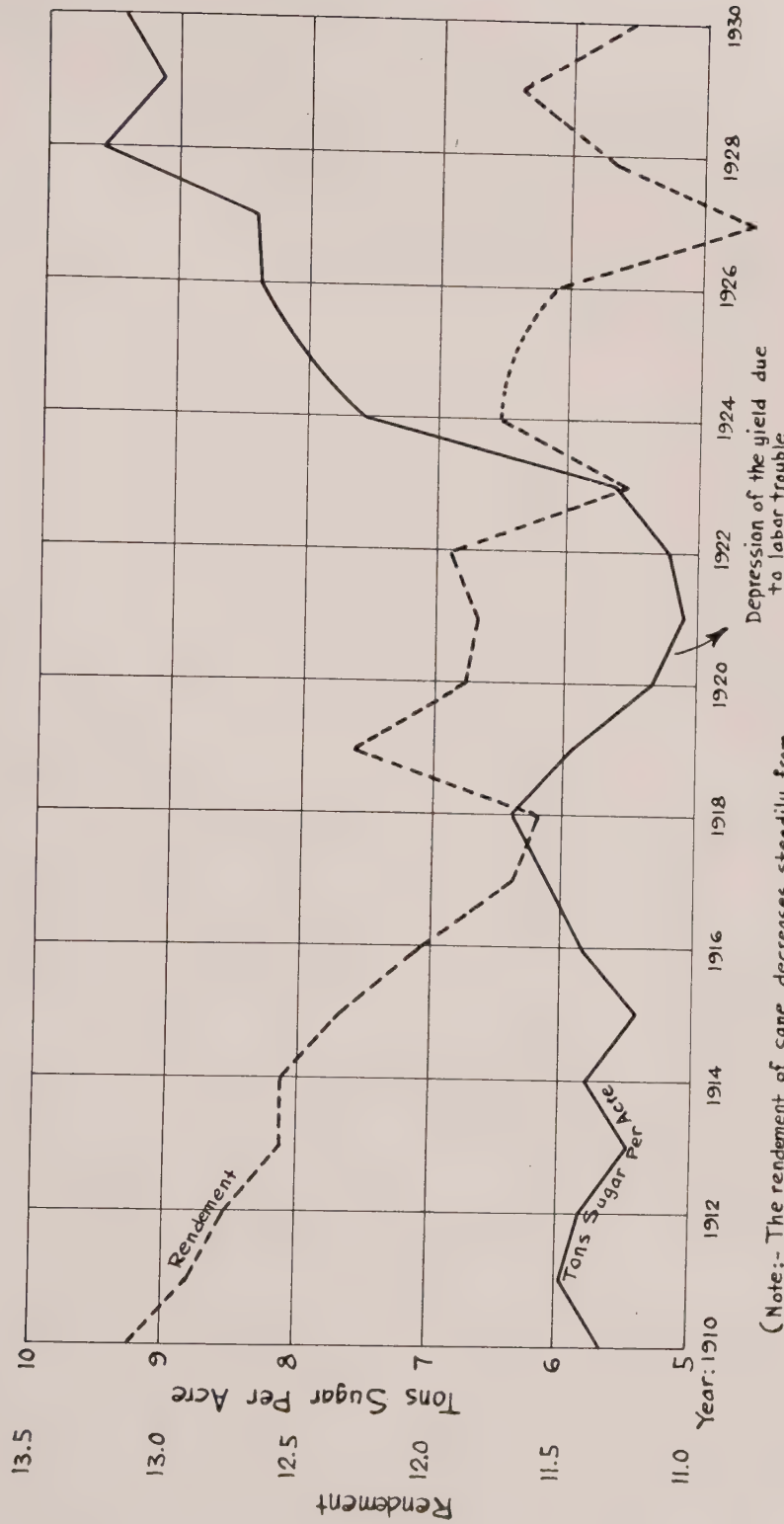
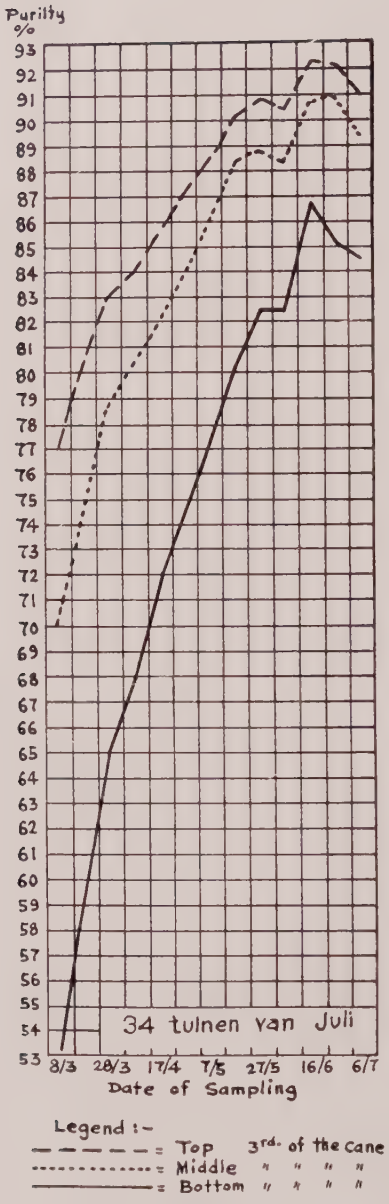

The Production Of Sugar Per Acre In Oahu Compared To The Average Quality Of Juice From 1910 To 1930.
Rendement
Tons Sugar Per Acre
Year: 1910
1912
1914
1916
1918
1920
1922
1924
1926
1928
1930
13.5
13.0
12.5
12.0
11.5
11.0
10
9
8
7
6
5
Rendement
Tons Sugar Per Acre
Depression of the yield due to labor trouble.
(Note:- The rendement of cane decreases steadily from 1910 to 1930 while the yield of sugar rises just as steadily).

Fig. 1



(After Kuyper in Java Archief)

Fig. 2. Note the steady improvement in the purity of juice of the bottom third, a long time after the attached leaves had died off.

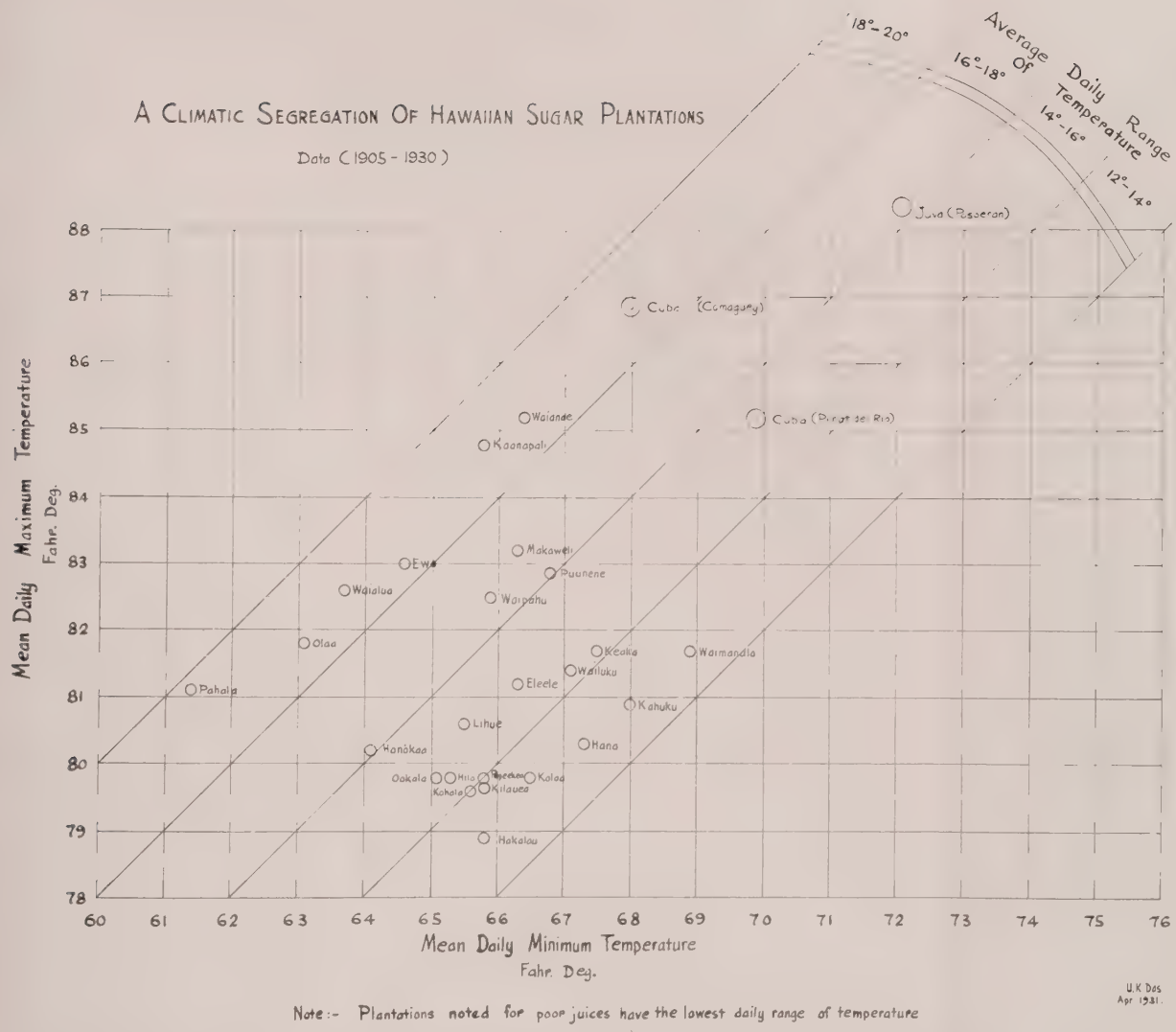


Fig. 3. In this figure the plantations have been located by their average annual maximum and average annual minimum temperature. For example, Ewa is seen to have an annual maximum temperature of 83° F. and annual minimum of 64.6° F. Diagonal lines have been drawn through points having equal differences between the annual maximum and annual minimum temperature. In the case of Ewa, the difference is 18.4°, therefore Ewa is seen to lie close to the 18° line of range of temperature. Java and Cuba have been located in the map for the sake of comparison. This figure and its implications are dealt with in greater detail in a forthcoming paper.

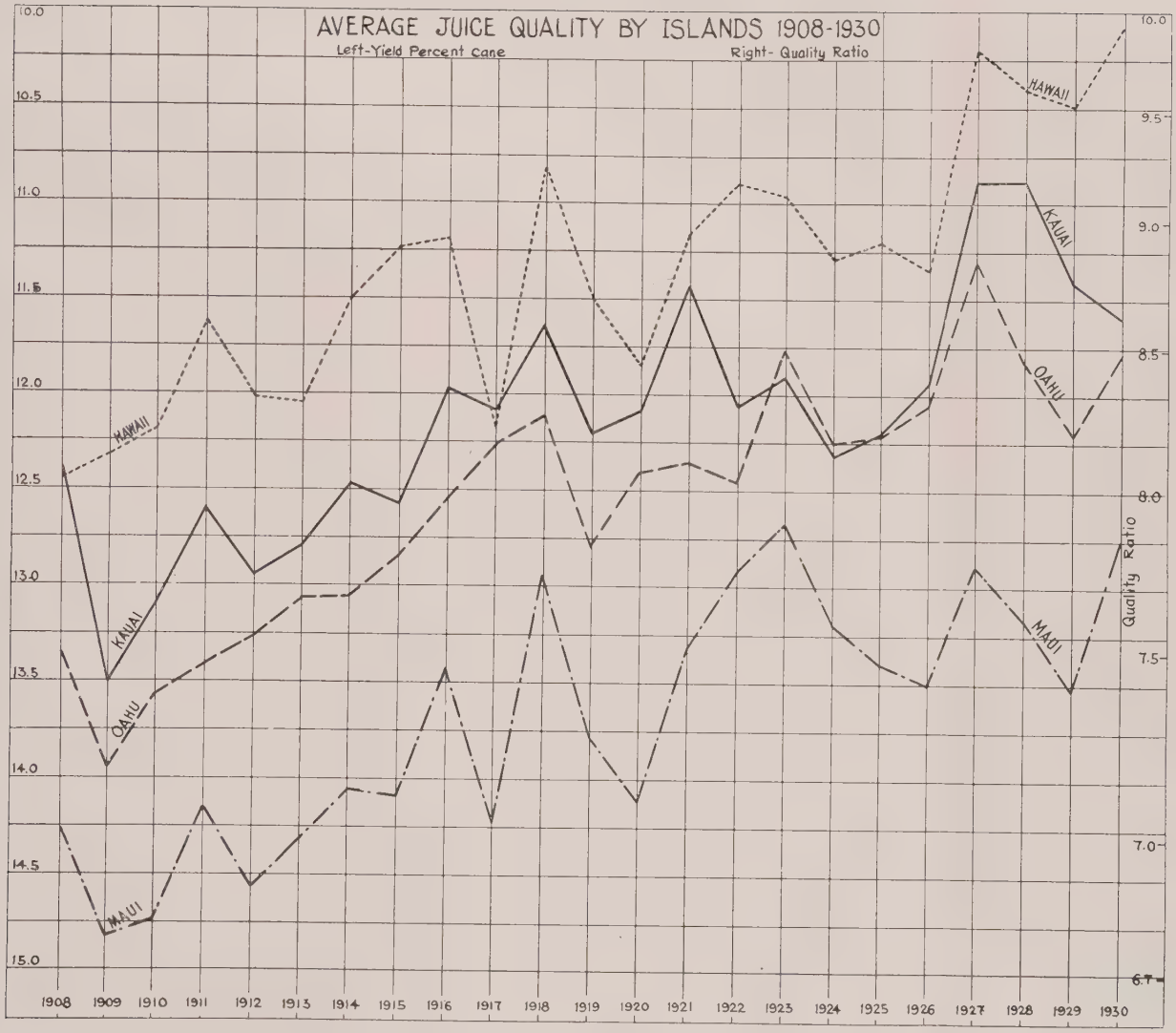


Fig. 4. The rise and fall of the juice curves of the four islands are very similar from year to year—this in spite of soil and varietal differences among the islands. Such a close relationship of the curves would suggest that some factors common to all the islands might have caused the fluctuations in the quality of juice from year to year. Weather conditions are believed to be the factors involved.

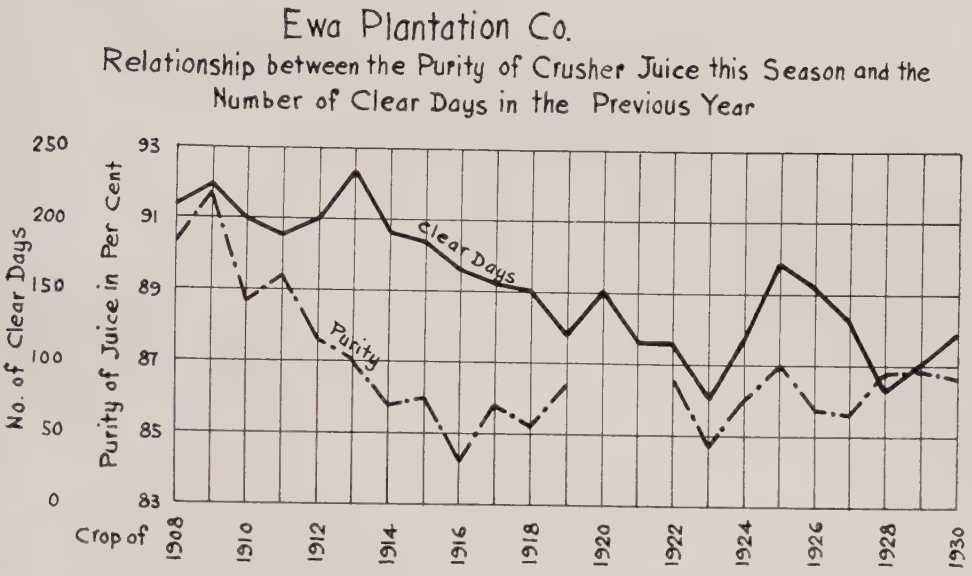


Fig. 5

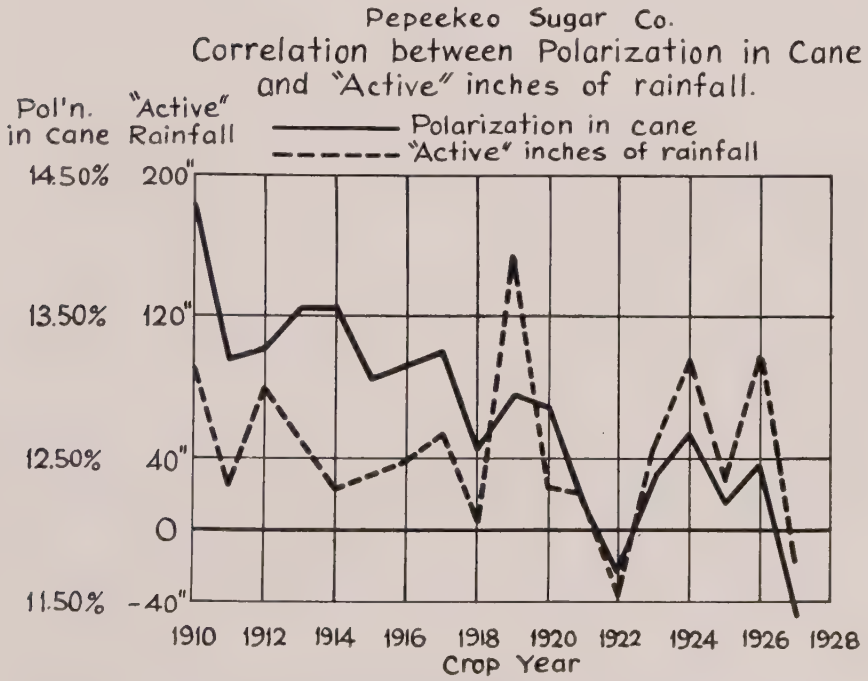
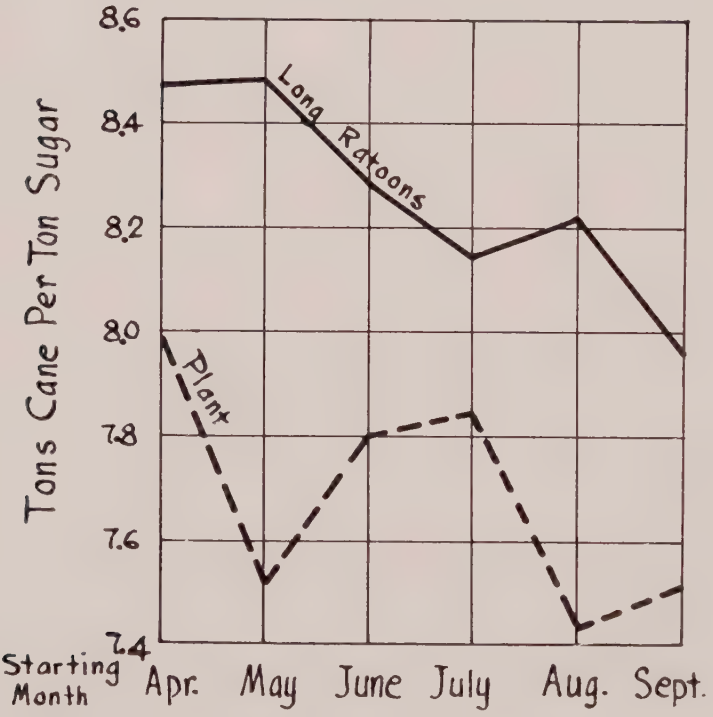


Fig. 6. "Active" inches of rainfall takes into consideration both the amount of rainfall in the growing season and the amount in the harvesting season. Plentiful rain in the growing season and a comparatively dry ripening and harvesting season make for good juice in unirrigated plantations. Details are to be found in *Hawaiian Planters' Record*, Vol. XXXII, 1928, p. 105.

Ewa Plantation Company
Avg. Of Crops (1924-1929) Variety H109
Time Of Starting The Crop On The Quality Of Juice Of
Long Ratoons And Plant Cane



(Note:- The quality of the juice tends to be better as the season of starting approaches the summer months).

Fig. 7

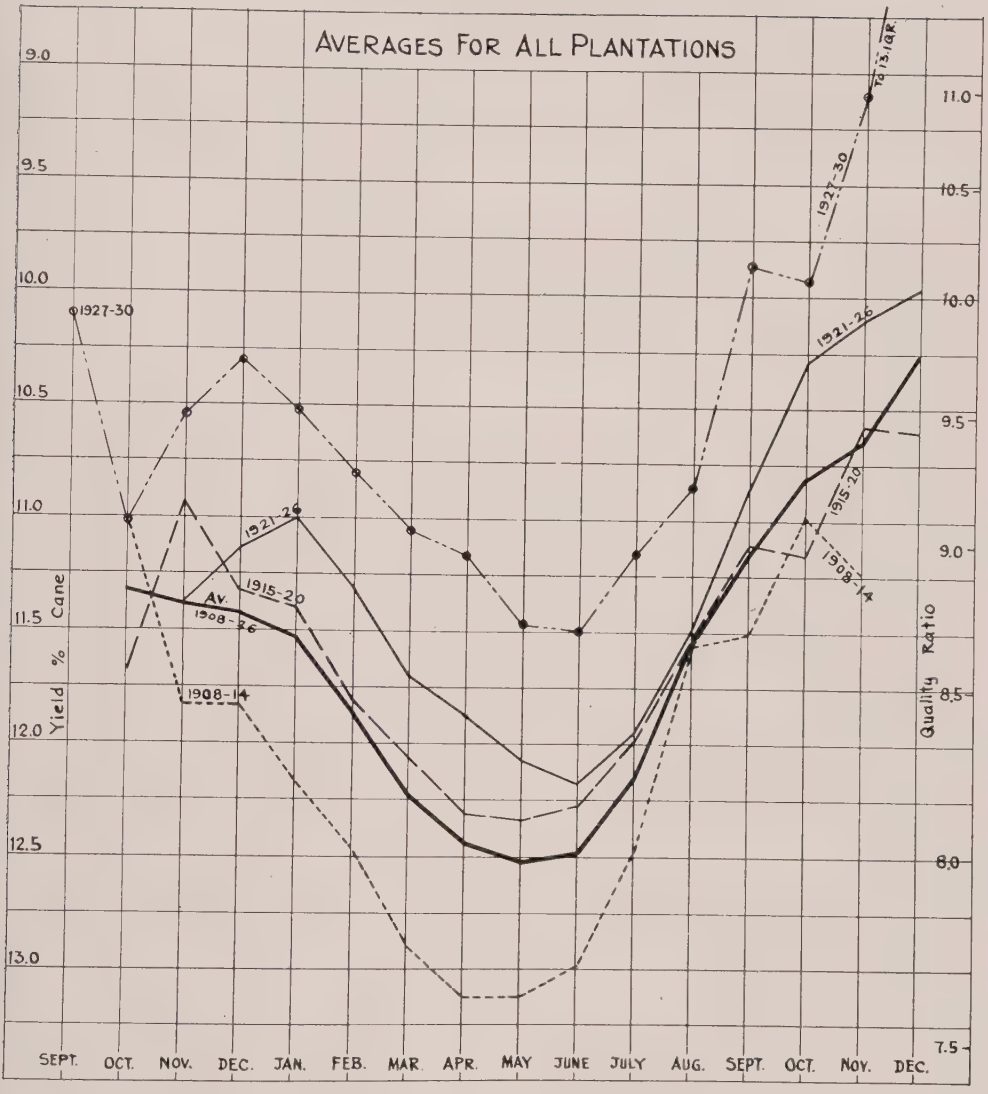


Fig. 8. In these Islands, canes harvested around the months of April, May and June give better juices, in general, than cane harvested at any other period—this, regardless of other factors.

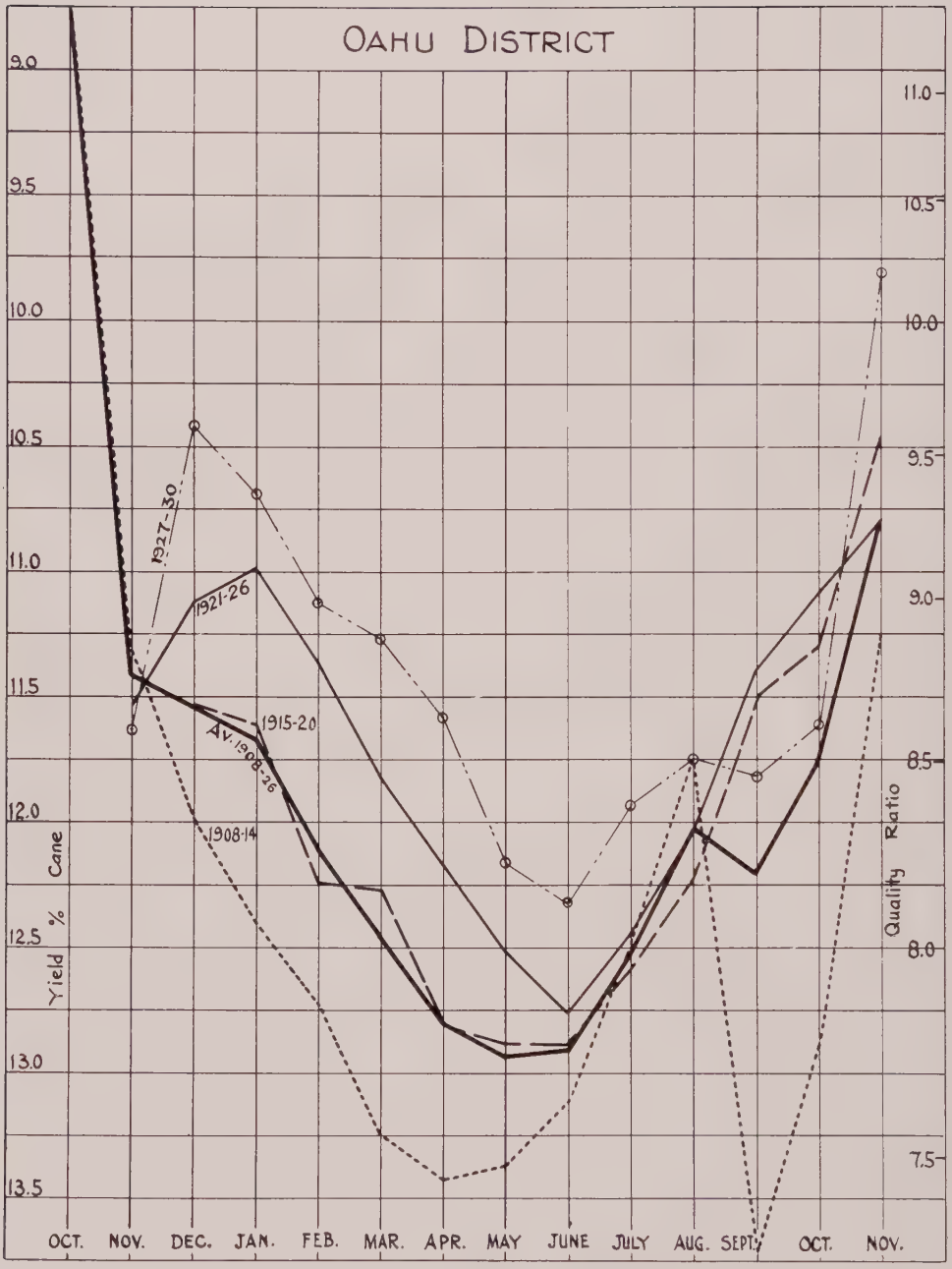


Fig. 9 (a). In 1908-1914, the best juices were obtained from cane harvested in April, in 1915-1920 in May, and in recent years in June. It is suggested that this shift of two months might be due to delayed maturity of cane under our present cultural conditions.

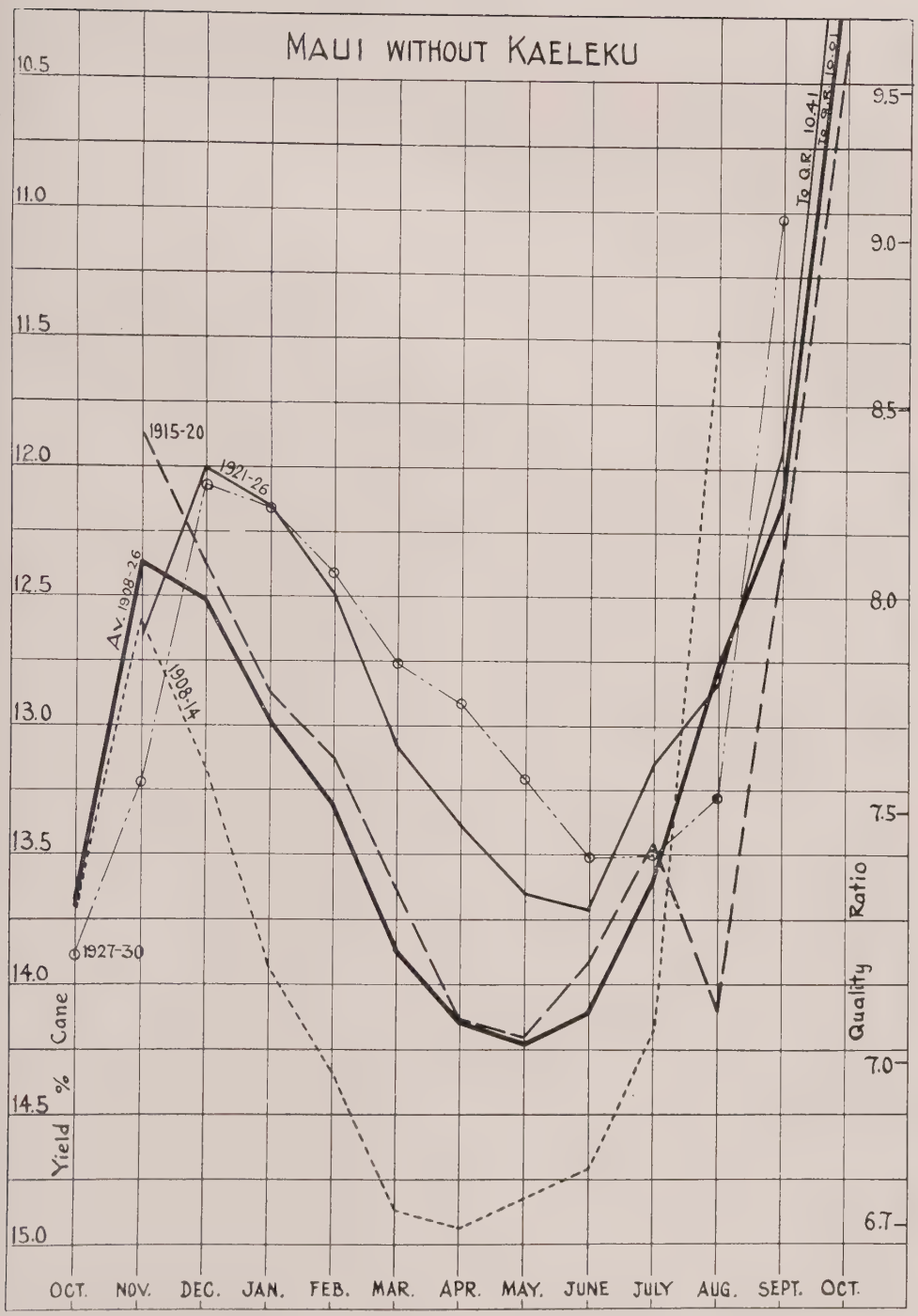


Fig. 9 (b). For explanatory legend see page 194.

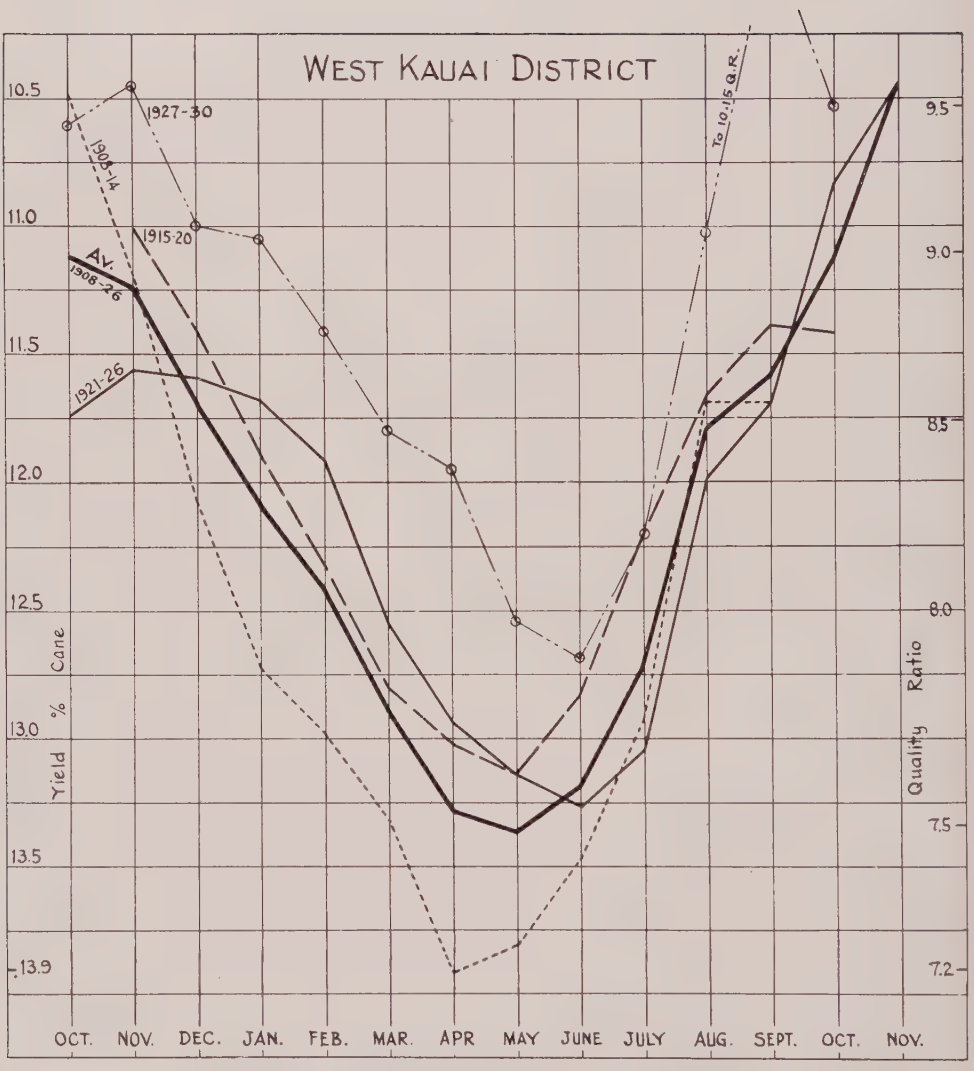


Fig. 9 (c). For explanatory legend see page 194.

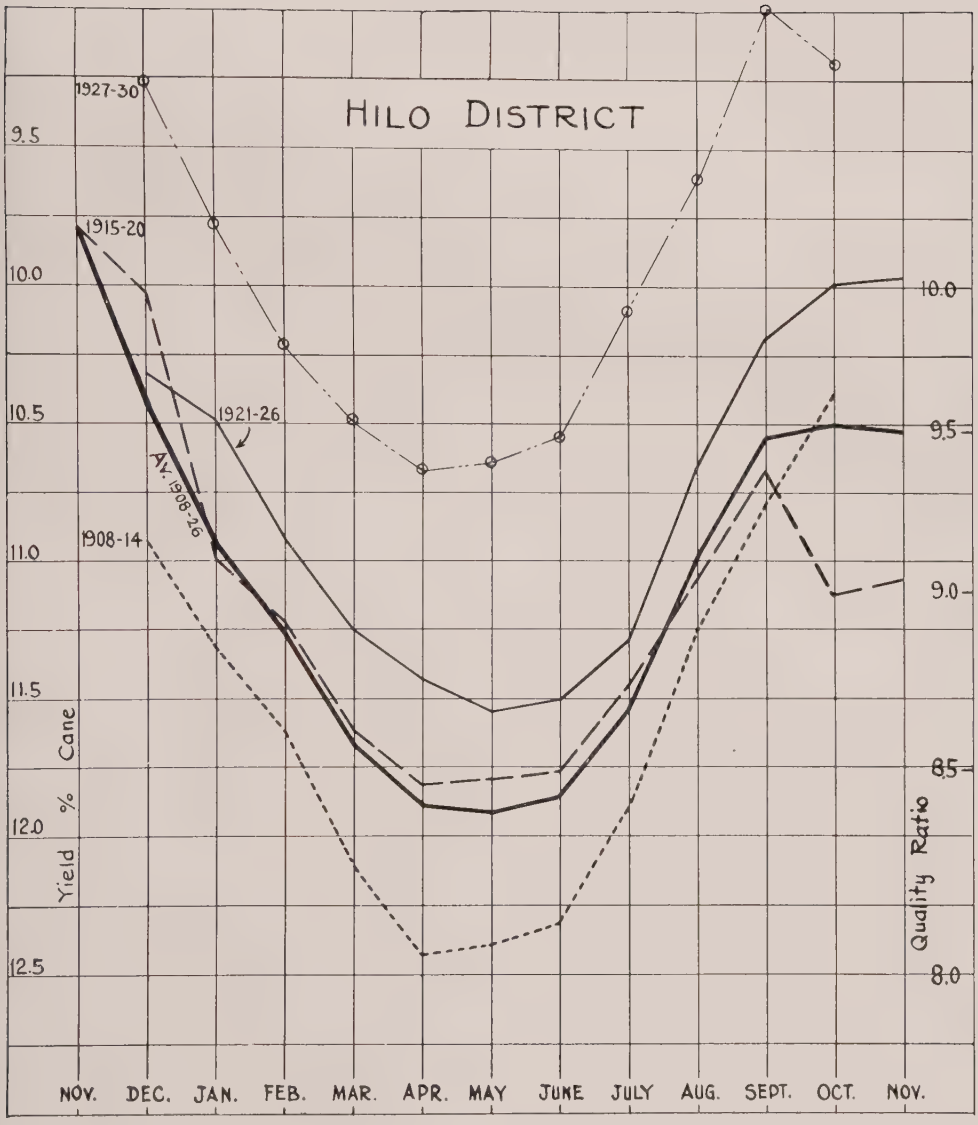


Fig. 9 (d). For explanatory legend see page 194.

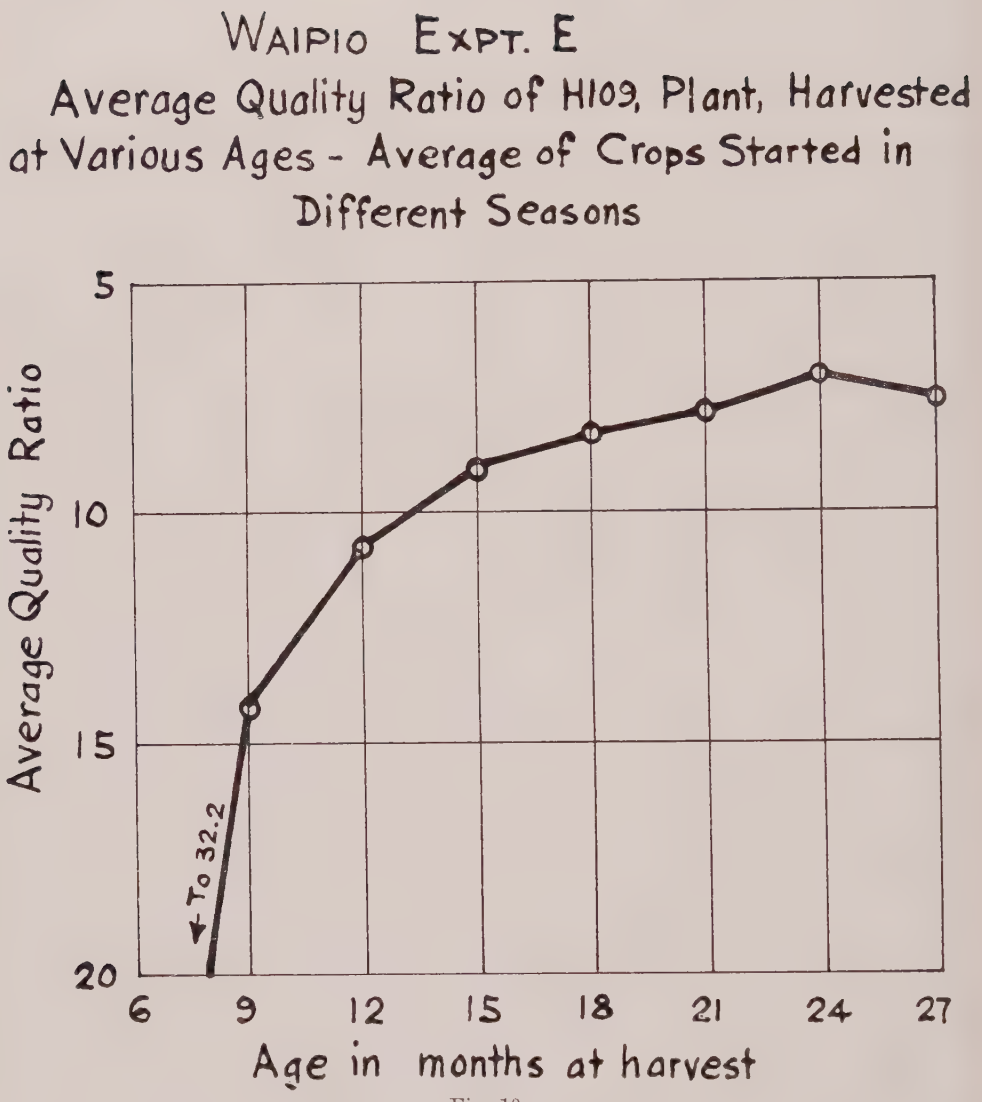

WAIPIO EXPT. E
Average Quality Ratio of H109, Plant, Harvested at Various Ages - Average of Crops Started in Different Seasons
Average Quality Ratio
5
10
15
20
To 32.2
6
9
12
15
18
21
24
27
Age in months at harvest

Fig. 10

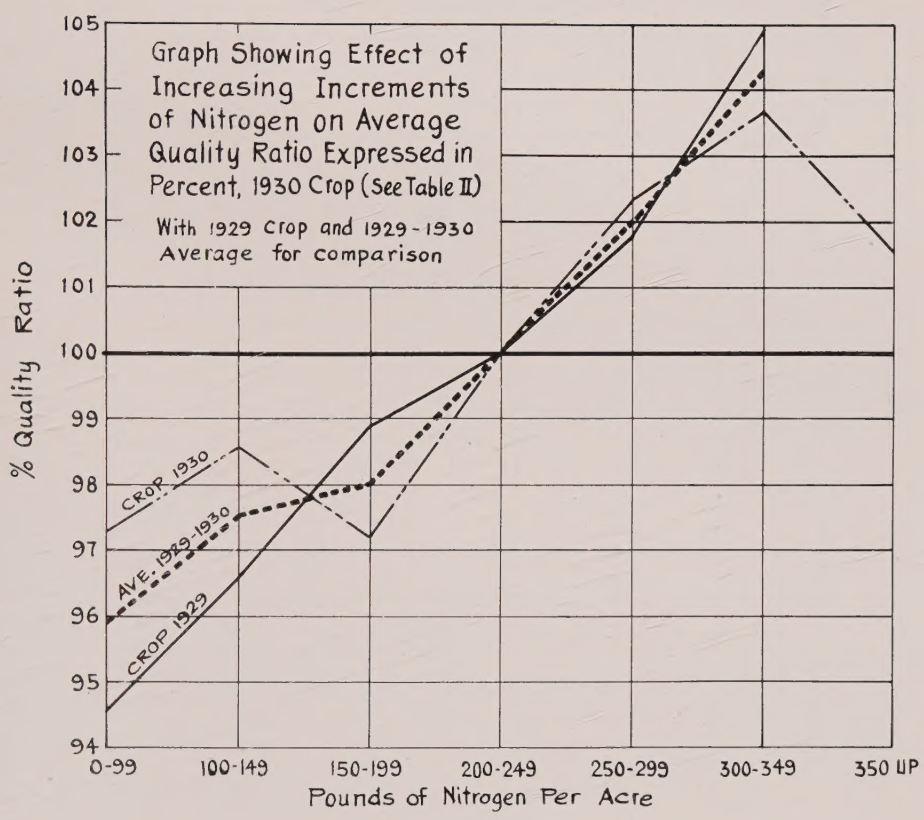

Graph Showing Effect of Increasing Increments of Nitrogen on Average Quality Ratio Expressed in Percent, 1930 Crop (See Table II)
With 1929 Crop and 1929-1930 Average for comparison
% Quality Ratio
105
104
103
102
101
100
99
98
97
96
95
94
CROP 1930
AVE. 1929-1930
CROP 1929
0-99
100-149
150-199
200-249
250-299
300-349
350 UP
Pounds of Nitrogen Per Acre

Fig. 11

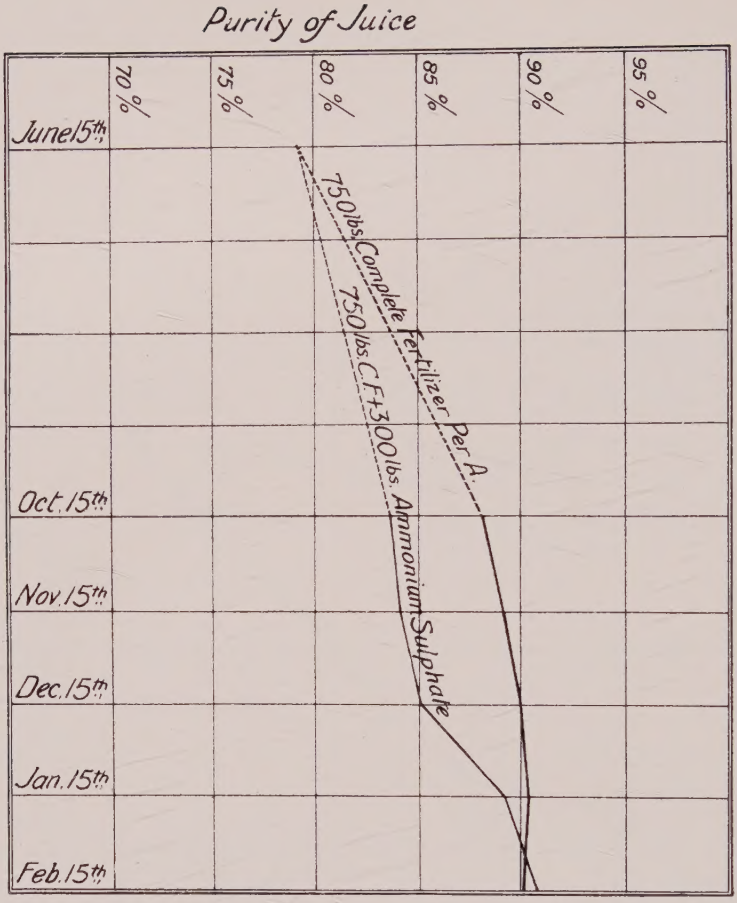
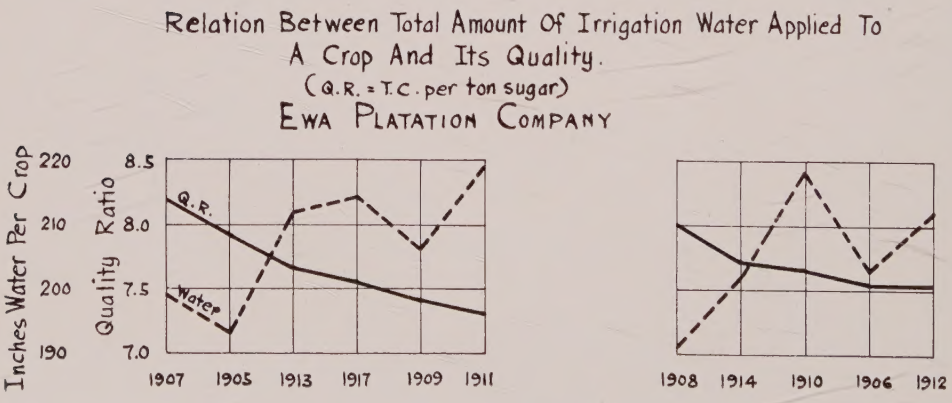


Fig. 12. Spring dressing of 300 lbs. N applied in May, 1909—all plots harvested in February, 1910, at the age of 24 months. Total nitrogen 180 lbs. per acre. Note that the plots receiving spring dressing are much slower in reaching maturity, but in February, 1910, both the treatments gave the same quality of juice.



(Data from "The sugar yields in a typical irrigated plantation of Hawaii, the Ewa Plantation Co, Planters' Record, Vol. XXXIV April, 1930)

Fig. 13

Sugar Prices

96° Centrifugals for the Period Dec. 16, 1930, to March 12, 1931.

Date	Per Pound	Per Ton	Remarks
Dec. 16, 1930	3.25¢	$65.00	Cubas.
" 23	3.23	64.60	Philippines.
" 24	3.22	64.40	Cubas.
" 29	3.145	62.90	Cubas, 3.15, 3.14.
" 31	3.25	65.00	Cubas.
Jan. 2, 1931	3.18	63.60	Philippines.
" 5	3.275	65.50	Philippines, 3.25, 3.30; Cubas, 3.30; Porto Ricos, 3.30.
" 6	3.37625	67.53	Philippines, 3.35, 3.38; Porto Ricos, 3.375; Cubas, 3.40.
" 7	3.3833	67.67	Philippines, 3.40, 3.37; Porto Ricos, 3.38.
" 8	3.40	68.00	Porto Ricos; Philippines.
" 12	3.41	68.20	Porto Ricos, 3.40; Cubas, 3.42.
" 13	3.39	67.80	Porto Ricos, 3.38, 3.40; Cubas, 3.40.
" 14	3.38	67.60	Cubas.
" 20	3.40	68.00	Porto Ricos.
" 21	3.39	67.80	Porto Ricos, 3.38; Cubas, 3.40.
" 22	3.40	68.00	Porto Ricos; Philippines.
" 26	3.37875	67.58	Philippines, 3.355, 3.39, 3.37; Cubas, 3.40.
" 29	3.35	67.00	Porto Ricos.
Feb. 3	3.315	66.30	Philippines, 3.30; Porto Ricos, 3.30; Cubas, 3.33.
" 4	3.29	65.80	Porto Ricos, 3.30; Philippines, 3.28.
" 5	3.30	66.00	Cubas; Philippines.
" 11	3.32	66.40	Porto Ricos.
" 17	3.30	66.00	Cubas; Philippines; Porto Ricos.
" 24	3.32	66.40	Cubas; Porto Ricos.
Mar. 2	3.28	65.60	Cubas.
" 3	3.25	65.00	Philippines; Porto Ricos.
" 6	3.23	64.60	Cubas; Porto Ricos; Philippines.
" 10	3.25	65.00	Cubas; Porto Ricos.
" 11	3.275	65.50	Porto Ricos, 3.25, 3.30.
" 12	3.25	65.00	Porto Ricos; Philippines.